MORRIS'S

TREATISE ON ANATOMY

FIFTH EDITION

PART I

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MORRIS'S

HUMAN ANATOMY

A COMPLETE SYSTEMATIC TREATISE
BY ENGLISH AND AMERICAN AUTHORS

EDITED BY

C. M. JACKSON, M. S., M. D.

PROFESSOR AND DIRECTOR OF THE DEPARTMENT OF ANATOMY,
UNIVERSITY OF MINNESOTA

ELEVEN HUNDRED AND EIGHTY TWO ILLUSTRATIONS
THREE HUNDRED AND FIFTY EIGHT PRINTED IN COLOURS

FIFTH EDITION, REVISED AND LARGELY REWRITTEN

IN FIVE PARTS

PART I

MORPHOGENESIS, OSTEOLOGY,
ARTICULATIONS

PHILADELPHIA
P. BLAKISTON'S SON & CO.
1012 WALNUT STREET

THE · MAPLE · PRESS · YORK · PA

ARRANGEMENT OF SUBJECTS AND AUTHORS

The names of the more recent of those who wrote or revised articles for previous editions have been retained in the following list in order that due credit should be given them for the work done and for their share in the great success which Morris's "Anatomy" has achieved.

MORPHOGENESIS. Revised and largely rewritten for the fifth edition by C. M. Jackson, M.S., M.D., Professor of Anatomy in the University of Minnesota. Originally written by J. Playfair McMurrich, A.M., Ph.D., Professor of Anatomy, University of Toronto.

OSTEOLOGY. Revised for the third, fourth and fifth editions by Peter Thompson, M.D., Professor of Anatomy, University of Birmingham; Member of Anatomical Society of Great Britain. This article was originally written by Sir John Bland Sutton, F.R.C.S.

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EDITOR'S PREFACE TO THE FIFTH EDITION

One criticism upon most of the current text-books of human anatomy is that they are too extensive for the beginner. Much precious time is wasted by him in floundering through a mass of details which obscure the fundamental facts. And yet it is important to have these details conveniently accessible for both present and future reference. To meet this difficulty, the attempt is made in this edition to discriminate systematically in the use of sizes of type. The larger type is used for the more fundamental facts, which should be mastered first, and the smaller type for details. While it has been found difficult to apply this principle uniformly through the various sections, it is hoped that the plan, even though but imperfectly realized, will prove useful to the beginner.

In the illustrations of the bones, as heretofore, the origins of muscles are indicated by red lines, the insertions by blue lines, and the attachments of ligaments by dotted black lines.

While the authors of the present edition are for the most part the same as in the previous edition, a few changes have been made as noted under the preceding section, "Arrangement of Subjects and Authors." Owing to the retirement of the distinguished originator and former editor of this work, Sir Henry Morris, and of Professor McMurrich as co-editor, the responsibility for the general supervision of the fifth revision has fallen to the present editor.

Each author is alone responsible for the subject-matter of the article following his name. Care has been exercised on the part of the editor, however, to make the whole uniform, complete and systematic.

As to nomenclature, the Anglicised form of the BNA has been continued, excepting those cases where the Latin form is adopted into English (e. g., most of the muscles), and rare cases where the BNA term seems undesirable. As a rule, the Anglicised form where first used is followed by the BNA Latin term *in brackets,* except where the two are practically identical. For convenience of reference, some of the commoner synonyms of the old nomenclature are also added in parenthesis.

The previous edition of Morris's Anatomy was the first general text-book of anatomy in English to adopt the BNA. During the past few years the merit of this system of nomenclature has become so widely recognized that it is now very generally accepted among the English-speaking nations. Lack of space forbids the enumeration here of the many advantages of this system, not the least of which is the reduction of some 30,000 anatomical terms (including synonyms) to 5000. The comparatively few defects of the BNA will doubtless be remedied by revision (preferably through the International Anatomical Congress). For a full discussion of the BNA system, with complete list of the Latin terms and English equivalents, the reader is referred to the excellent work on the BNA by Professor L. F. Barker, of Johns Hopkins University.

In addition to the bibliographical references scattered throughout the text, a brief list is given at the close of each section. These brief lists of carefully selected references are intended merely as a guide to put the student "on track" of the original literature.

In addition to a thorough revision of the various sections, there has also been a rearrangement of a part of the subject matter in the present edition. The Teeth have been transferred from the section on Osteology to the Digestive System. The Tongue and Nose are transferred to the Digestive System and Respiratory System, respectively, excepting those portions forming the organs of Taste and Smell, which have been retained in the section on Special Sense Organs. The Pelvic Outlet has been discontinued as a separate section, the subject matter being divided between Musculature and Clinical and Topographical Anatomy. The Ductless Glands have been included in the section with the Skin and Mammary Glands.

Due credit has been given throughout the book wherever illustrations have been taken, or modified, from other works. Special acknowledgment should be made of our indebtedness to the works of Toldt, Rauber-Kopsch, Poirier and Charpy, Henle and Spalteholz.

The number of figures in the present edition has been increased about one hundred and sixty and in addition many of the older figures have been improved or replaced. For the generosity of the publishers in this connection, and for the hearty coöperation of the contributors in the revision of the various sections, the editor desires to express his deep indebtedness. Valuable assistance has been rendered by Mr. Walter E. Camp in the reading of proof and preparation of the index.

C. M. Jackson.

Minneapolis.

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INTRODUCTION

By C. M. JACKSON, M.S., M.D.

PROFESSOR OF ANATOMY, UNIVERSITY OF MINNESOTA.

ANATOMY, as the term is usually employed, denotes the study of the structure of the human body. Properly, however, it has a much wider significance, including within its scope not man alone, but all animal forms, and, indeed, plant forms as well; so that, when its application is limited to man, it should be qualified by the adjective human. *Human Anatomy*, then, is the study of the structure of the human body, and stands in contrast to, or rather in correlation with, *Human Physiology*, which treats of the functions of the human body, the two sciences, Anatomy and Physiology, including the complete study of man's organization and functional activities.

In the early history of the sciences these terms sufficed for all practical needs, but as knowledge grew, specialization of necessity resulted and new terms were from time to time introduced to designate special lines of anatomical inquiry. With the improvement of the microscope a new field of anatomy was opened up and the science of *Histology* came into existence, assuming control over that portion of Anatomy which dealt with the minuter details of structure. So, too, the study of the development of the various organs gradually assumed the dignity of a more or less independent study known as *Embryology*, and the study of the structural changes due to disease was included in the science of *Pathology;* so that the term Anatomy is sometimes limited to the study of the macroscopic structure of normal adult organisms.

It is clear, however, that the lines of separation between Anatomy, Histology, Embryology, and Pathology are entirely arbitrary. Microscopic anatomy necessarily grades off into macroscopic anatomy; the development of an organism is a progressive process and the later embryonic or fœtal stages shade gradually into the adult; and structural anomalies lead insensibly from the normal to the pathological domains. Furthermore it is found that in its individual development the organism passes through stages corresponding to those of its ancestry in evolution; in other words, Ontogeny repeats Phylogeny. A comprehensive study of Anatomy must therefore include more or less of the other sciences, and since an appreciation of the significance of structural details can only be obtained by combining the studies of Anatomy, including Histology and Embryology, and since, further, much light may be thrown on the significance of embryological stages by comparative studies, Anatomy, Embryology, and Comparative Anatomy form a triumvirate of sciences by which the structure of an organism, the significance of that structure, and the laws which determine it are elucidated. For this combination it is convenient to have a single term, and that which is used is *Morphology*, a word meaning literally the science of form.

In morphological comparisons, the term *homology* denotes similarity of structure, due to a common origin in the evolution of organs or parts; while *analogy* denotes merely physiological correspondence in function. Thus the arm of man and the wing of a bird are homologous, but not analogous, structures; on the other hand, the wing of a bird and the wing of an insect are analgous, but not homologous. *Serial homology* refers to corresponding parts in successive segments of the body.

Nomenclature.—Formerly there was much confusion in the anatomical nomenclature, due to the multiplicity of names and the lack of uniformity in using them. Various names were applied to the same organs and great diversity of usage prevailed, not only between various countries, but also even among authors of the same country. Recently, however, a great improvement has been made by the general adoption of an international system of anatomical nomen-

clature. This system was first adopted by the German Anatomical Society at a meeting in Basel, in 1895, and is hence called the Basel Nomina Anatomica, or briefly, the BNA. The BNA provides each term in Latin form, which is especially desirable for international usage. Each nation, however, is expected to translate the terms into its own language, wherever it is deemed preferable for everyday usage. Thus in the present work the Anglicised form of the BNA is generally used. Where not identical, however, the Latin form is added once for each term in a place convenient for reference, and is designated by enclosure in brackets [ ]. Where necessary the older terms have also been added as synonyms.

The Commission by whom the BNA was prepared included eminent anatomists representing various European nations. The work of the Commission was very thorough and careful, and extended through a period of six years. Among the guiding principles in the difficult task of selecting the most suitable terms were the following: (1) Each part should have one name only. (2) The names should be as short and simple as possible. (3) Related structures should have similar names. (4) Adjectives should be in opposing pairs. A few exceptions were found necessary, however.

On account of its obvious merits, the BNA system has been generally adopted throughout the civilised world, and the results are very satisfactory. Comparatively few new terms have been thereby introduced, over 4000 of the 4500 names in the BNA corresponding almost exactly to older terms already in use by the English-speaking nations. Certain minor defects in the system have been criticised; but these are outweighed by the advantages of this uniform system.

Abbreviations.—Certain frequently used words in the BNA are abbreviated as follows: a., arteria (plural, aa., arteriæ); b., bursa; g., ganglion; gl., glandula; lig., ligamentum (plural, ligg., ligamenta); m., musculus (plural, mm., musculi); n., nervus (plural, nn., nervi); oss., ossis (or ossium); proc., processus; r., ramus (plural, rr., rami); v., vena (plural, vv., venæ).

Terms of position and direction.—The exact meaning of certain fundamental terms used in anatomical description must be clearly understood and kept in mind. In defining these terms, it is supposed that the human body is in an upright position, with arms at the sides and palms to the front.

The three **fundamental planes** of the body are the sagittal, the transverse and the frontal. The vertical plane through the longitudinal axis of the trunk, dividing the body into right and left halves, is the *median* or *mid-sagittal* plane; and any plane parallel to this is a *sagittal* plane. Any vertical plane at right angles to a sagittal plane, and dividing the body into front and rear portions is a *frontal* (or coronal) plane. A plane across the body at right angles to sagittal and coronal planes is a *transverse* or *horizontal* plane.

Terms pertaining to the front of the body are *anterior* or *ventral*; to the rear, *posterior* or *dorsal*; upper is designated as *superior* or *cranial*; and lower as *inferior* or *caudal*.

The term *medial* means nearer the mid-sagittal plane, and *lateral*, further from that plane. These terms should be carefully distinguished from internal (inner) and external (outer), which were formerly synonymous with them. *Internal*, as now used (BNA), means deeper, i. e., nearer the central axis of the body or part; while *external* refers to structures more superficial in position. *Proximal*, in describing a limb, refers to position nearer the trunk; while *distal* refers to a more peripheral position.

'Adverbial forms are also employed, e. g., anteriorly or ventrally (forward, before); posteriorly or dorsally (backward, behind); superiorly or cranially (upward, above); and inferiorly or caudally (downward, below).

It should also be noted that the terms ventral, dorsal, cranial and caudal are independent of the body posture, and therefore apply equally well to corresponding surfaces of vertebrates in general with horizontal body axis. On this account these terms are preferable, and will doubtless ultimately supplant the terms anterior, posterior, superior and inferior.

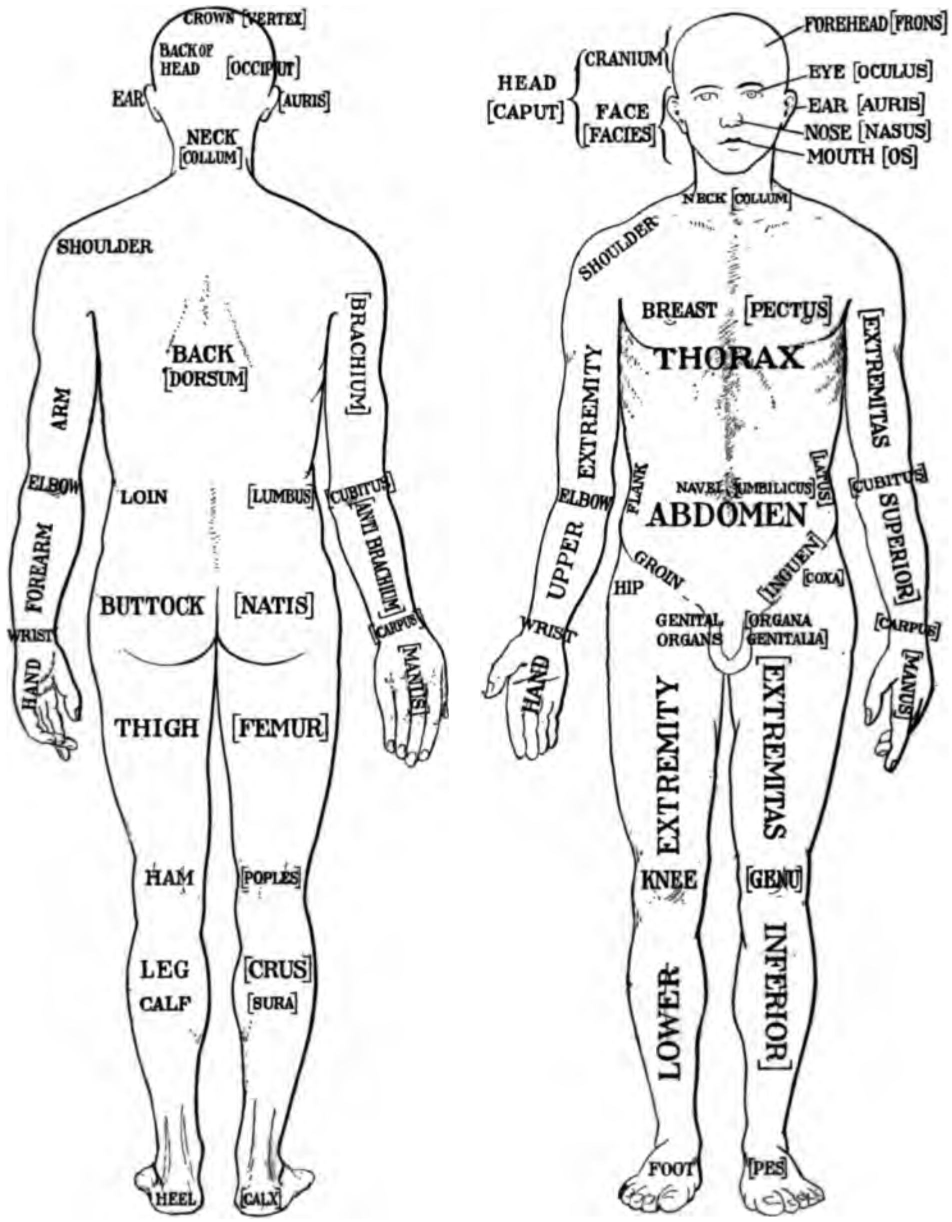
The discrimination in the use of several similar terms of the BNA should also receive attention. Thus *medianus* (median) refers to the median plane. *Medialis* (medial) means nearer the median plane and is opposed to lateral, as above stated. *Medius* (middle) is used to designate a position between anterior and posterior, or between internal and external. Between medialis and lateralis, however, the term *intermedius* is used. Finally, *transversalis* means transverse to the body axis; *transversus*, transverse to an organ or part; and *transversarius*, pertaining to some other structure which is transverse.

Parts of the body.—The primary divisions of the human body (fig. 1) are the head, neck, trunk and extremities. The *head* [caput] includes *cranium* and *face* [facies]. The *neck* [collum] connects head and trunk. The *trunk* [truncus] includes *thorax*, *abdomen*, and *pelvis*. The *upper extremity* [extremitas superior] includes *arm* [brachium], *forearm* [antibrachium], and *hand* [manus]. The

lower extremity [extremitas inferior] includes *thigh* [femur], *leg* [crus], and *foot* [pes].

Each of the parts mentioned has further subdivisions, as indicated in fig. 1. The cranium includes: *crown* [vertex]; *back* of the head [occiput]; *frontal* region [sinciput], including *forehead* [frons]; *temples* [tempora]; *ears* [aures], including *auricles* [auriculæ].

FIG. 1.—PARTS OF THE HUMAN BODY. A, Posterior view. B, Anterior view.



The face includes the regions of the *eye* [oculus], *nose* [nasus], and *mouth* [os], the subdivisions of which will be given later under the appropriate sections.

The thorax includes: *breast* [pectus]; *mammary gland* [mamma]; and *thoracic cavity* [cavum thoracis]. The *back* [dorsum] includes the vertebral column [columna vertebralis]. The abdomen includes: *navel* [umbilicus]; *flank* [latus]; *groin* [inguen]; *loin* [lumbus]; and the *abdominal cavity* [cavum abdominis]. The pelvis includes: *pelvic cavity* [cavum pelvis]; *genital organs* [organa genitalia],

buttocks [nates], separated by a cleft [crena ani] at the *anus*. The *hip* [coxa] connects the pelvis with the lower extremity.

In the lower extremity, the thigh is joined to the leg by the *knee* [genu]. The foot includes: *heel* [calx]; *sole* [planta]; *instep* [tarsus]; *metatarsus;* and five *toes* [digiti I–V], including the *great toe* [hallux] and *little toe* [digitus minimus].

The upper extremity is joined to the thorax by the *shoulder*. The arm is joined to the forearm at the *elbow* [cubitus]. The hand includes: *wrist* [carpus];

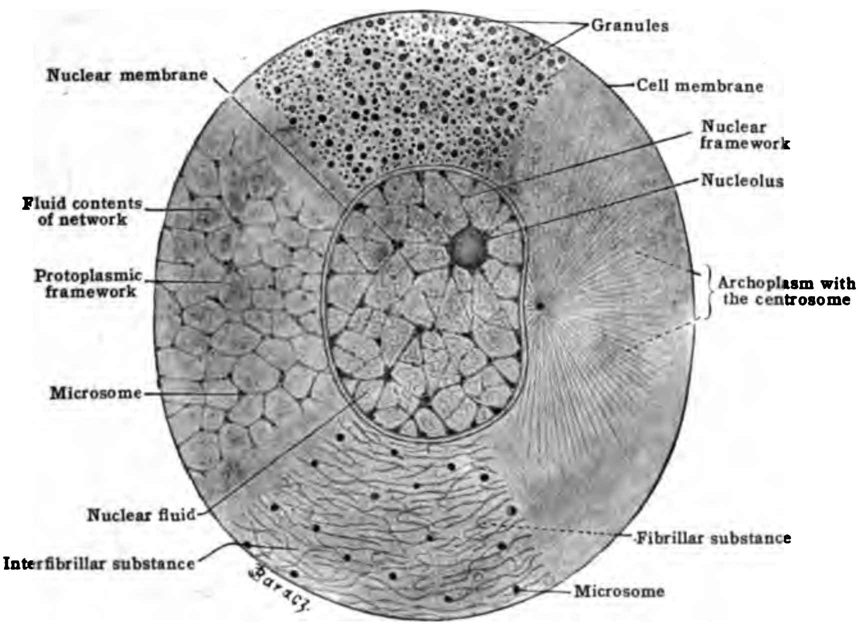
FIG. 2.—SECTION OF THE EPIDERMIS OF A FINGER, FROM A HUMAN EMBRYO OF 10.2 CM.

metacarpus, with *palm* [vola or palma] and *back* [dorsum manus]. The five *fingers* [digiti I–V] include: *thumb* [pollex], *index* finger [index]; *middle* finger [digitus medius]; *ring* finger [digitus annularis] and *little* finger [digitus minimus].

Organ-systems.—Each of the various parts of the body above outlined is composed of various *organs,* and the groups of related organs make up *organ-systems.*

The various organ-systems are treated as special branches of descriptive anatomy. The study of the *bones* is called *osteology;* of the *ligaments* and *joints,*

FIG. 3.—DIAGRAM OF A TYPICAL CELL. (Szymonowicz.)



syndesmology (or arthrology); of the *vessels, angiology*; of the *muscles, myology;* of the *nervous system, neurology*; and of the *viscera, splanchnology*. Further subdivisions are also made. The viscera, for example, include the *digestive* tract, *respiratory* tract, *urogenital* tract, etc.

Tissues and cells.—The body, as above stated, has various parts, each of which may be subdivided into its component systems and organs. A further analysis reveals a continued series of structural units of gradually decreasing complexity. Thus each organ is found to consist of a number of *tissues* (epithelial, connective, muscular or nervous). Finally, each tissue is composed of a group of similar units called *cells* (figs. 2, 3) which are the ultimate structural units

of the body. The body may therefore be regarded as composed of myriads of cell units, organized into units of gradually increasing complexity, very much as a social community is composed of individuals organized into trades, municipalities, etc.

Most of the individual tissues can be recognized by their gross appearance. In fact, the principal tissues were first demonstrated by Bichat through skilful dissection, maceration, etc., and without the aid of the microscope. The cellular structure of the tissues was later discovered by Schwann in 1839.

Each cell (fig. 3) is composed of a material called *protoplasm*, a viscid substance variable in appearance and exceedingly complex in chemical composition. It readily breaks down into simpler chemical compounds, whereby energy (chiefly in the form of heat and mechanical energy) is liberated. It has also the power of absorbing nutritive material to build up and replace what was lost. Its decomposition results from stimuli of various kinds, and hence it is said to be irritable. The mechanical energy which it liberates is manifested by its contractility, especially in the muscle cells. It excretes the waste products produced by its decomposition. Each cell has the power, under favourable conditions, of reproducing itself by division. Protoplasm presents, in short, all the forms of activity manifested by the body as a whole; and, indeed, the activities of the body are the sum of the activities of its constituent cells.

In the protoplasm of each cell is a specially differentiated portion, the *nucleus* (fig. 3). The nucleus plays an important part in regulating the activities of the *cytoplasm*, the general protoplasm of the cell body. The nucleus differs from the cytoplasm both structurally and chemically, and contains a very important substance, *chromatin*, which during cell division is aggregated into a definite number of masses called *chromosomes*. The cytoplasm of actively growing cells also contains the *archoplasm* and *centrosome*, structures of importance in the process of cell division. Further details concerning the cells and tissues may be found in the text-books of cytology and histology.

In earlier days Human Anatomy was almost entirely a descriptive science, but little attention being paid to the significance of structure, except in so far as it could be correlated with physiological phenomena as they were at the time understood. In recent years attention has been largely paid to the morphology of the human body and much valuable information as to the meaning of the structure and relations of the various organs has resulted. Since the form and structure of the body are the final result of a series of complicated developmental changes, the science of Embryology has greatly contributed to our present knowledge of human Morphology; and, accordingly, a brief sketch of some of the more important phases of morphogenesis will form a fitting introduction to the study of the adult.

References.—*General:* For looking up the literature upon any anatomical topic, the best guide is the "Jahresbericht ueber die Fortschritte der Anatomie und Entwicklungsgeschichte," which contains classified titles and brief abstracts of the more important papers in gross anatomy, histology and embryology. Other useful aids are the "Zentralblatt fuer normale Anatomie," the "Index Medicus" and the catalogue of the Surgeon Genera 's Library of the War Dep't. (Washington, D. C.). The latter two contain titles only, but cover the whole field of medicine. The "Concilium Bibliographicum" also provides a convenient card-index system of references for the biological sciences, including Anatomy.

For *nomenclature:* His, Archiv f. Anat., 1895 (BNA system); Barker, Anatomical Nomenclature. *Cells and tissues:* Wilson, The Cell; Hertwig, Zelle und Gewebe (also English transl.); Schaefer, Microscopic Anatomy (in Quain's Anatomy, 11th ed.); Heidenhain, Plasma und Zelle.

SECTION I

MORPHOGENESIS

REVISED FOR THE FIFTH EDITION

BY C. M. JACKSON, M.S., M.D.

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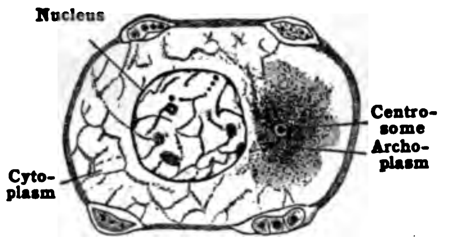
CHANGE is a fundamental characteristic of all living things. The human body during its life cycle accordingly passes through various phases of form and structure. In the earliest embryonic phases of development the changes are very rapid, decreasing in rapidity during the later fœtal stages, but continuing at a diminishing rate throughout infancy, childhood and youth up to the adult. Following the acme of maturity, changes continue which lead gradually to senescence and final death of the body.

This cycle of change in the body depends upon similar changes in its various component organs, each having its own characteristic life cycle. In a few of the organs this cycle is very short, as in some of the organs of the embryo (e. g., mesonephros). Other organs persist only during childhood (e. g., thymus); while the majority continue, with varying degrees of change, throughout postnatal life. The final death of the body is due to the breakdown of some of the essential organs.

A further analysis reveals the fact that the characteristic life cycles of the organs depend ultimately upon similar changes in their constituent tissues and cells. Every cell has a definite life cycle, an early period characterised by rapid and vigourous changes, later periods of differentiation and maturity, followed by stages of degeneration and death. This cycle of cell changes has been designated by Minot as *cytomorphosis*.

Growth.—Associated with the process of cell differentiation (cytomorphosis), and even more important as a factor in the morphogenesis of the body, is the process of *growth*. The developmental changes in form and structure of the body are due largely to the unequal growth of its various parts. Growth, like other changes in the body and its parts, depends ultimately upon the characteristics of the constituent cells.

FIG. 4.—THE OVUM OF A NEW-BORN CHILD, WITH FOLLICLE CELLS. (After Mertens.)



The cell changes during growth may be grouped under two heads. The first, or growth proper, involves merely the *enlargement* (hypertrophy) of the individual cells and intercellular products. The second includes the *multiplication* (hyperplasia) of the cells, which is accomplished by mitotic division. Cell division is necessary in cell growth, for otherwise the cell would soon reach a size where its surface (for nutritive, respiratory and excretory purposes) would be inadequate for its mass. In general, however, cell division is most active in the earlier embryonic periods, during which the cells remain small. Later, cell division diminishes or ceases, and growth is due chiefly to enlargement of the cells already present. It is also during the later period, when the cells have ceased rapid division, that the process of cell differentiation and tissue formation is most marked.

The principle of the *ratio of surface to mass* often applies to the growing organs as well as to the individual cells. To maintain the necessary ratio, the surface area is increased by the formation, through localised unequal growth, of *projections* (e. g., villi or folds) or *invaginations* (e. g., glands) from surfaces. Innumerable modifications of this principle occur throughout the process of morphogenesis.

FIG. 5.—OVUM FROM OVARY OF A WOMAN THIRTY YEARS OF AGE. *cr*, corona radiata. *n*, nucleus. *y*, yolk. *p*, clear protoplasmic zone, *ps*, perivitelline space. *zp*, zona pellucida. (McMurrich's Embryology, from Nagel.)

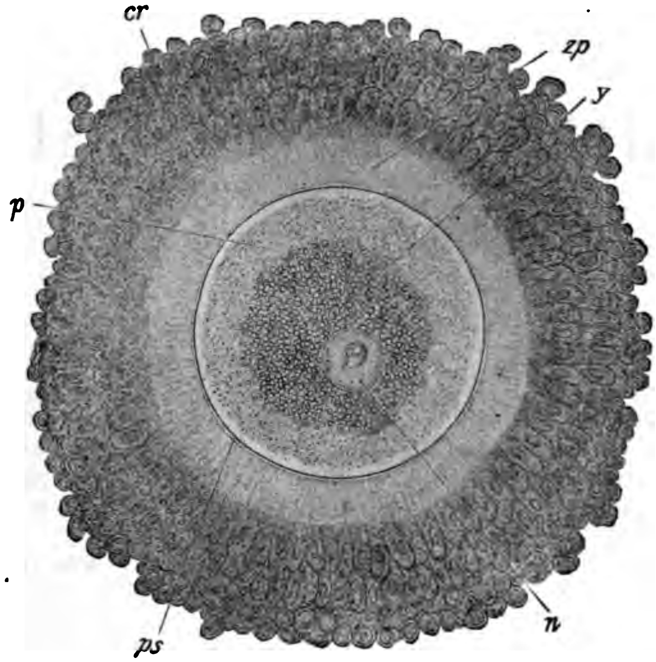
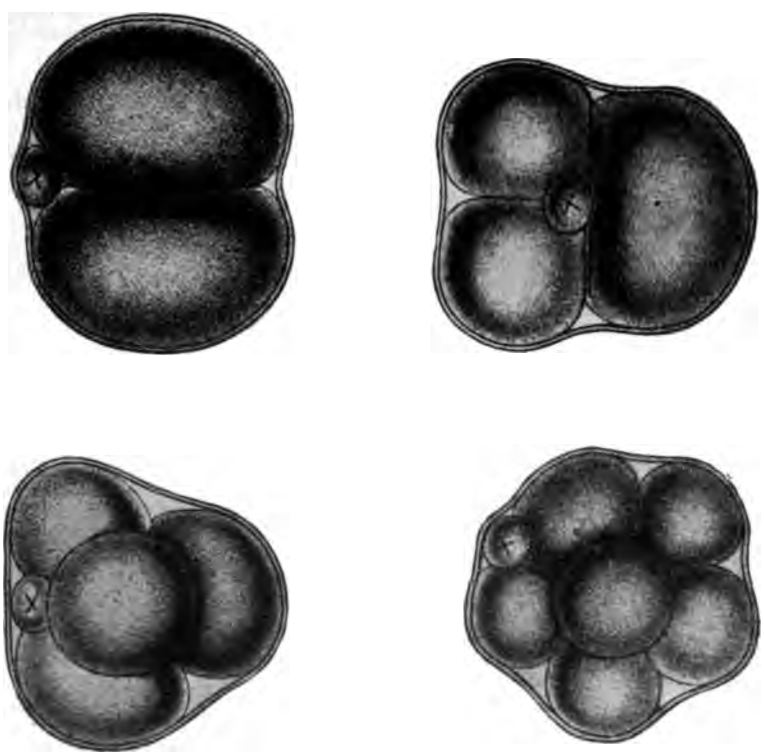


FIG. 6.—STAGES OF SEGMENTATION IN THE OVUM OF THE MOUSE. *x*, polar body. (McMurrich's Embryology, from Sobotta.)

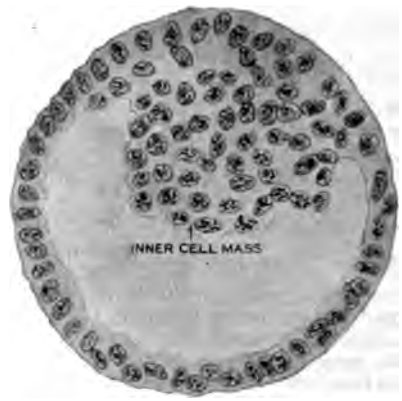


While the present work deals primarily with the adult human organism in the stage of maturity, reference is made also to its changes according to age. Although these changes for the various systems of organs are described under the appropriate sections, it is desirable to consider first some of the more fundamental features pertaining to the body as a whole. This applies particularly to the earlier embryonic period, which includes the more general phases of morphogenesis. No attempt will be made to describe fully the process of development, the details of which are to be found in text-books of embryology.

Segmentation of the ovum.—The human body, like all living organisms, arises from a single cell, the egg-cell or *ovum*. An early stage in the development of the ovum is shown in fig. 4, and a later stage, approaching maturity, in fig. 5. The mature human ovum is about 0.2 mm. in diameter. In the uterine (Fallopian) tube, the fertilised ovum undergoes segmentation, the various stages of which are represented in figs. 6 and 7.

FIG. 7.—DIAGRAM OF SECTION THROUGH A MAMMALIAN OVUM AT THE MORULA STAGE.

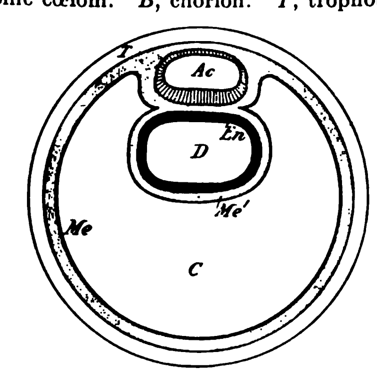
FIG. 8.—DIAGRAM OF SECTION OF A MAMMALIAN OVUM SHOWING THE INNER CELL MASS.



While the processes of maturation, fertilisation and segmentation have not as yet been observed in the human ovum, the evidence of comparative anatomy makes it very probable that in all essential respects these processes are like those found in other mammals. As a result of the successive divisions of the ovum in segmentation, a spherical mass of cells, the *morula* (fig. 7) is formed. In this mass, an excentric cavity forms (fig. 8) whereby the mass is transformed into a hollow vesicle. The wall of this vesicle is probably formed throughout the greater part of its extent by a single layer of cells; but at one point of the circumference there is a group of cells termed the *inner cell mass* (fig. 8). Probably about this time the ovum enters the uterine cavity, and through the activity of the outer layer of cells (*trophoblast*) becomes embedded in the uterine mucosa.

Formation of the embryonic disc and germ layers.—In the earliest human embryos which have been described, development has already proceeded beyond

FIG. 9.—DIAGRAM SHOWING THE RELATIONS OF THE GERM LAYERS IN AN EARLY EMBRYO. *Ac*, amniotic cavity, lined by ectoderm. *D*, yolk-sac, lined by endoderm (*En*). *Me,Me'*, mesoderm, *C*, extra-embryonic cœlom. *B*, chorion. *T*, trophoblast. (McMurrich.)



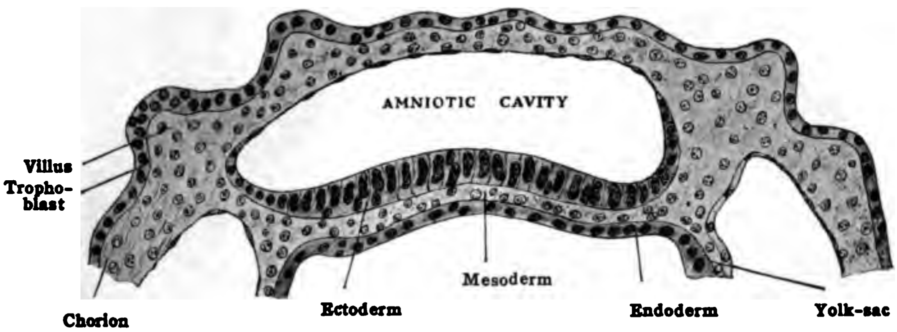
the stage represented by fig. 8, and has reached that of fig. 9. Within the inner cell mass, two cavities have appeared. The more superficial (ac) is the *amniotic*

cavity; the deeper (D) is the cavity of the *yolk-sac;* while between them is a plate of cells forming the *embryonic disc.* The embryonic disc (figs. 9 and 10) contains three layers of cells,—the fundamental *germ layers,*—*ectoderm* (Ec), *endoderm* (En), and *mesoderm.*

The germ layers of the embryonic disc are of prime importance in the development of the body. From the *ectoderm,* which lies next to the amniotic cavity and represents the upper (later outer) germ layer, are derived the epidermis and the entire nervous system. From the *endoderm,* which lies next to the yolk-sac, and represents the lower (later inner) germ layer, is derived the epithelial lining of the digestive mucosa and its derivatives. From the *mesoderm,* or middle germ layer, is differentiated the remainder of the body, including the skeletal and supporting tissues, vascular system, muscle and most of the urogenital organs.

The germ layers also extend beyond the embryonic disc, as shown in figs. 9 and 10. The *yolk-sac* is made up of a lining of endoderm and an outer layer of mesoderm. The *amnion,* which

FIG. 10.—DIAGRAM OF SECTION OF A MAMMALIAN OVUM SHOWING THE EMBRYONIC DISC, AMNIOTIC CAVITY AND THE GERM LAYERS.

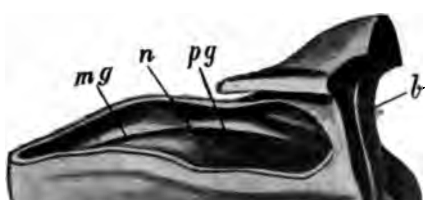


later becomes separated from the chorion, is composed of mesoderm lined by endoderm. The outer cell layers form the *chorion,* which likewise shows two layers, the outermost of which (trophoblast) is ectoderm, the inner, mesoderm. In fig. 10 the chorion is beginning to send out root-like projections (villi) which invade the uterine mucosa.

It is thus noteworthy that of the cells derived from the ovum relatively only a few—those of the embryonic disc—enter directly into the formation of the body. The yolk-sac, a rudimentary organ of phylogenetic significance, is later chiefly absorbed, although the proximal portion may enter slightly into the formation of the intestinal wall. The amnion is a protective membrane, while the chorion forms the fœtal part of the placenta.

Development of the embryonic disc.—When first formed, the surface of the embryonic disc shows no trace of differentiation. A slightly later but still comparatively early stage in its development is shown in fig. 11. It is here

FIG. 11.—MODEL SHOWING THE EMBRYONIC DISC FROM AN EMBRYO 1.17 MM. IN LENGTH. Viewed from above and laterally, the roof of the amniotic cavity having been removed. *n,* primitive pit (neurenteric canal). *pg,* primitive groove. *mg,* neural groove. *b,* body-stalk. (McMurrich, from Frassi.)



viewed from above, the amnion having been removed. The disc is an elliptical plate, whose long axis represents the mid-line of the embryo. Near the center is a small rounded depression, the *primitive pit.* Extending backward (toward the tail end of the embryo) from this is a dark line, the *primitive streak,* corresponding to a groove, the *primitive groove.* Extending forward from the primitive pit is an indistinct wide shallow groove, the *neural groove.*

At an earlier stage, the primitive streak extends further forward, possibly to the anterior end of the embryonic disc (Spee). The primitive streak and groove probably correspond to the

fused lips of a primitive blastopore. They represent a centre of proliferation from which the mesoderm is budded off from the ectoderm and spreads out to form the middle germ layer of the embryonic disc.

At the anterior end of the primitive streak this proliferation extends forward as a plate of cells, the so-called *'head process.'* The axial portion of this process is the anlage of the *notochord*, the embryonic skeletal axis. It contains a canal, which opens into the primitive pit. The notochordal anlage soon fuses with the underlying endoderm, and its canal forms the transient *neurenteric canal.*

In the mid-line anterior to the primitive streak there appears the shallow *neural groove* (fig. 11), corresponding to a thickened plate of ectodermic cells, the *neural plate.* The neural groove is slightly forked at its posterior extremity, in the region of the *primitive node* (Hensen's node), which forms the dorsal lip of the primitive pit. As development proceeds, the neural plate extends posteriorly, and the primitive pit is accordingly shifted backward, the corresponding part of the primitive groove being converted into 'head process.' The primitive streak thus becomes progressively shortened (cf. figs. 11 and 13).

FIG. 12.—TOPOGRAPHY OF THE EMBRYONIC DISC. DIAGRAM OF RELATIONS AT THE LENGTH OF ABOUT 1 MM. *ng*, neural groove. *pn*, primitive node. *pp*, primitive pit. *U*, upper limb. *L*, lower limb.

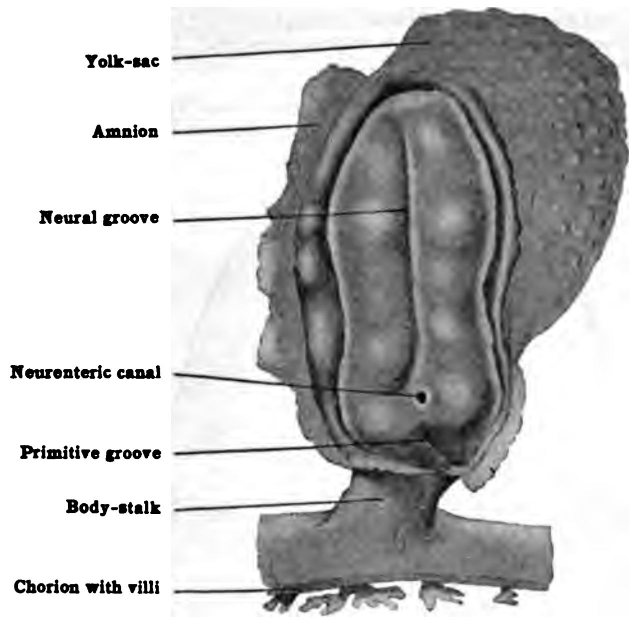
Topography of the embryonic disc.—Although only slight signs of differentiation are visible in the embryonic disc at the stage shown in fig. 11, it is already possible to map out more or less definite areas corresponding to all the various regions of the future body, as shown in fig. 12.

Beginning anteriorly, the head region is relatively enormous in size, occupying at this time the entire portion in front of the primitive pit and forming about half of the entire disc. The cervical, thoracic, lumbar and sacro-coccygeal regions appear successively smaller, approaching the posterior end ('tail bud') of the primitive streak. It is also a striking fact that the future dorsal region of the body wall, corresponding to the central portion of the disc, along each side of the mid-line, is now larger than the ventro-lateral regions, which occupy a relatively narrow area around the periphery of the disc.

The topography of the germinal areas in the embryonic disc shown in fig. 12 is based partly upon a study of the succeeding stages of development, and partly upon the results of experiments upon the germinal disc in lower forms, especially in the chick (Assheton, Peebles, Kopsch).

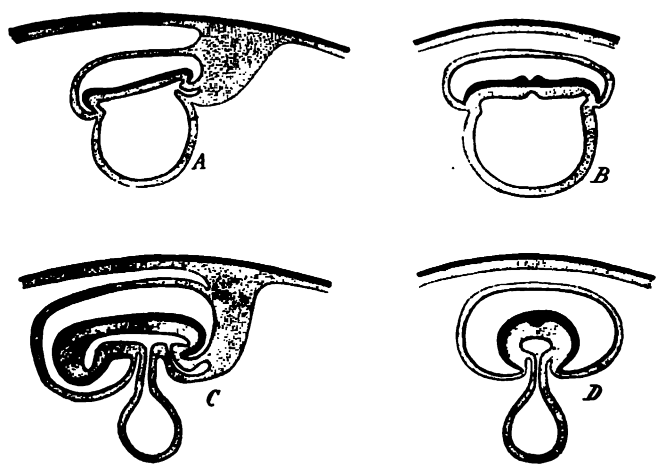
Law of developmental direction.—In the relative size of the various embryonic areas is foreshadowed what may be termed the law of direction in development. In general it is found that development (including growth and differentiation) in

FIG. 13.—HUMAN EMBRYO 1.54 mm. long. Viewed from above, the roof of the amniotic cavity having been removed. (Minot, after Graf Spee.)



the long axis of the body appears first in the head region and progresses toward the tail region. Similarly in the transverse plane development begins in the mid-dorsal region and progresses latero-ventrally (in the limbs, proximo-distally). These principles are of great importance in morphogenesis.

FIG. 14.—DIAGRAMS SHOWING THE CONSTRICTION OF THE EMBRYO FROM THE YOLK-SAC. *A* and *C*, longitudinal sections; *B* and *D*, corresponding cross-sections. (McMurrich.)

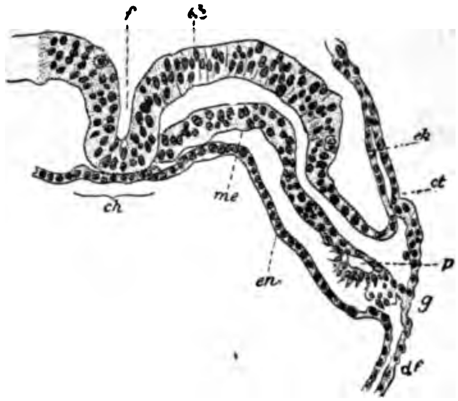


The law of developmental direction is also probably of phylogenetic significance. The *cranio-caudal* direction of development is in accordance with the theory that the head is the most primitive portion of the body, and hence precocious in development. The trunk is perhaps a secondary acquisition, hence arising as an extension of the primitive head region.

The *dorso-ventral* direction of development, together with the plate-like form of the embryonic disc, has a different phylogenetic significance. Both are probably inherited from an ancestral type with a yolk-laden ovum. In such an ovum, with the meroblastic type of segmentation, the flattened embryonic disc gradually spreads from the dorsal surface in a ventral direction around the underlying yolk-mass.

Derivation of body tube from embryonic disc.—The primary result of the precocious growth in the dorsal region of the embryonic disc is the conversion of the disc into the body tube, curved ventrally in its long axis (fig. 14).

FIG. 15.—PORTION OF CROSS SECTION OF THE EMBRYO SHOWN IN FIG. 13. *ch*, notochord. *ct*, somatic mesoderm. *df*, splanchnic mesoderm. *g*, junction of extra-embryonic somatic and splanchnic mesoderm. *ek*, ectoderm. *en*, endoderm. *me*, embryonic mesoderm. *f*, neural groove, *p*, beginning of embryonic cœlom (pericardial cavity). (Minot, after Graf Spee.)



As a result of the more rapid expansion of the germ layers (especially the ectoderm) near the mid-line, the dorsal surface of the embryonic disc in general becomes convex, with a depression laterally (where growth is less rapid) forming a groove at the line of attachment of the amnion (figs. 11, 12, 13, 14 B). The unequal growth in the germ layers is clearly evident in the cross section shown in fig. 15. By a continuation of this process, the margins of the embryonic disc become still further depressed and finally folded in ventrally so as to transform the disc into a tube (fig. 14 D). Similarly, by a more rapid expansion of the dorsal layer of the disc in the longitudinal axis, the head and tail ends of the disc are folded and tucked in ventrally, and the primitive body tube is thus correspondingly curved in its long axis (figs. 14 A, 14 C).

FIG. 16.—MODEL OF HUMAN EMBRYO 1.8 MM. LONG. Viewed from above, the roof of the amniotic cavity having veen removed. Near the caudal end of the neural groove, the primitive pit (opening of neurenteric canal) is visible. The primitive somites are appearing in the occipital region, the fourth corresponding to the boundary between head and neck. (McMurrich, from Keibel and Elze.)

The embryonic disc is thus converted into a tube composed of an outer layer of ectoderm, a middle layer of mesoderm and an inner layer of endoderm. The yolk-sac now presents an expanded *yolk-vesicle* lined by endoderm which is still continuous through the constricted *yolk-stalk* with the endoderm lining the primitive *enteric cavity* (fig. 14 C). The enteric cavity (or archenteron) has a blind tubular prolongation (fore gut) into the head region, and another (hind gut) into the tail region. From the latter a slender diverticulum, the *allantois*, extends into the body stalk (later the umbilical cord). The allantois is an organ of phylogenetic importance, with which the urinary bladder is later connected.

Formation of the neural tube.—The principle of unequal growth applies to the formation not only of the body as a whole, but also of its constituent parts. Thus the anlage of the nervous system arises from the ectoderm as a wide groove

whose edges (neural ridges) by local growth are folded upward so as to meet in the mid-line where they fuse, thus transforming the groove into the *neural tube* (figs. 11, 12, 13, 15, 16, 17, 18).

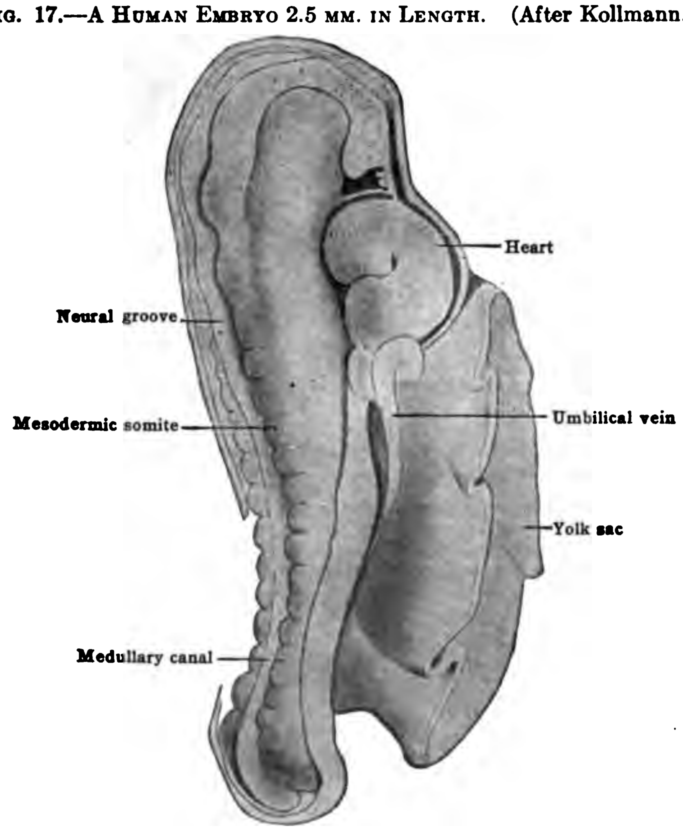
The closure begins, not at the anterior end (as might be expected from the general law of cranio-caudal development), but in the cervical region, extending forward into the brain region, and backward along the spinal cord. Thus the extreme ends (anterior and posterior neuropores) are the last to close.

The precocious and energetic growth of the neural anlage is largely responsible for the ventral flexure of the embryonic body axis, especially in the head region, where the flexures of the brain are very conspicuous (figs. 22, 26).

With the closure of the neural tube dorsally and of the alimentary canal ventrally the human embryo assumes the typical vertebrate form. The cylindrical body wall now encloses two tubes (neural and enteric) with the longitudinal axis (notochord) between them (figs. 18, 24).

After the embryonic disc has been transformed into a tube, the body of the human embryo in cross section appears not circular but elongated dorso-ventrally. This is the typical form for vertebrates with horizontal body axis. In later fœtal stages, the body becomes more rounded in cross section, and finally, with the assumption of the erect posture in postnatal life, becomes decidedly flattened dorso-ventrally (figs. 20, 21).

FIG. 17.—A HUMAN EMBRYO 2.5 MM. IN LENGTH. (After Kollmann.)



Development of the mesoderm.—The mesodermic layer on each side of the notochord in the embryonic disc develops in two divisions. The medial (or dorsal) divisions form a series of hollow segments, the *somites* (figs. 16, 17, 18). The lateral (later ventral) divisions each split into an upper (outer) or somatic layer and a lower (inner) or visceral layer. When the embryonic disc becomes folded, the corresponding somatic and visceral layers unite ventrally and enclose between them the common *cœlom* or primitive body cavity (fig. 18).

As previously noted, the mesoderm arises chiefly from the lateral portions of the 'head process.' A comparatively early stage before the appearance of the somites is shown in cross section in fig. 15. The somites appear first in the occipital region, and rapidly differentiate successively in the cranio-caudal direction (figs. 16, 17, 22). In embryos 7 or 8 mm. in length, about 40 somites may be distinguished, 3 to 5 occipital, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 5 or 6 coccygeal (in the rudimentary tail region).

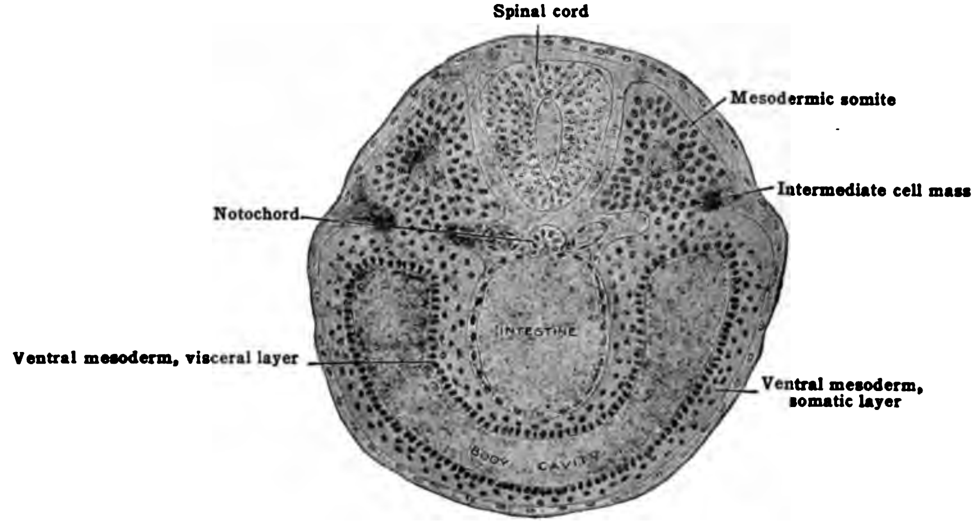
The *cœlom* or body cavity is unsegmented. Two primitive pericardial cavities appear sepa-

rate at first, but soon fuse and unite with the general cœlom. Later the general cœlom becomes secondarily divided into the permanent pericardial, pleural and peritoneal cavities.

The outer layer of the lateral mesodermic division forms the somatic or parietal layer of the peritoneum, etc. The inner layer forms the visceral or splanchnic layer, and develops not only the serous membrane, but also the muscular and connective tissue of the walls of the alimentary canal and its derivatives.

Development of the somites. Metamerism.—The appearance of the somites marks the beginning of *metamerism*, the arrangement of the body in successive

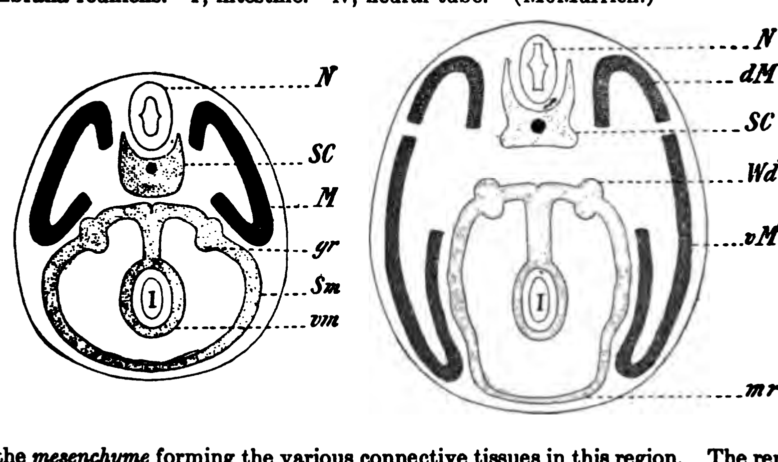
FIG. 18.—DIAGRAM OF A CROSS SECTION OF A HUMAN EMBRYO.



segments or metameres. Each somite develops a primitive muscle segment, *myotome*, and a skeletal segment, *sclerotome* (figs. 18, 19). Moreover, the corresponding nerves and blood-vessels likewise assume a metameric arrangement. This metamerism persists (more or less modified) in the adult neck and trunk.

The differentiation of the somites is illustrated by figs. 18 and 19. The medial wall of each somite forms the *sclerotome*. Its cells migrate to form the corresponding vertebra, rib, etc., as

FIG. 19.—DIAGRAMS ILLUSTRATING THE HISTORY OF THE MESODERM. *M*, myotome, *dM*, dorsal portion of myotome. *vM*, ventral portion of myotome. *SC*, sclerotome. *gr*, genital ridge. *Wd*, Wolffian duct. *Sm*, somatic layer of mesoderm. *vm*, visceral layer of mesoderm. *mr*, membrana reuniens. *I*, intestine. *N*, neural tube. (McMurrich.)



well as the *mesenchyme* forming the various connective tissues in this region. The remainder of the somite forms the *myotome*, from which the voluntary musculature of the trunk, the neck and (in part) the head is derived. The dorsal portions of the myotomes develop the muscle in the dorsal region of the trunk, while the ventral portions extend ventralward to form the musculature of the latero-ventral body walls (figs. 19, 20, 21, 23).

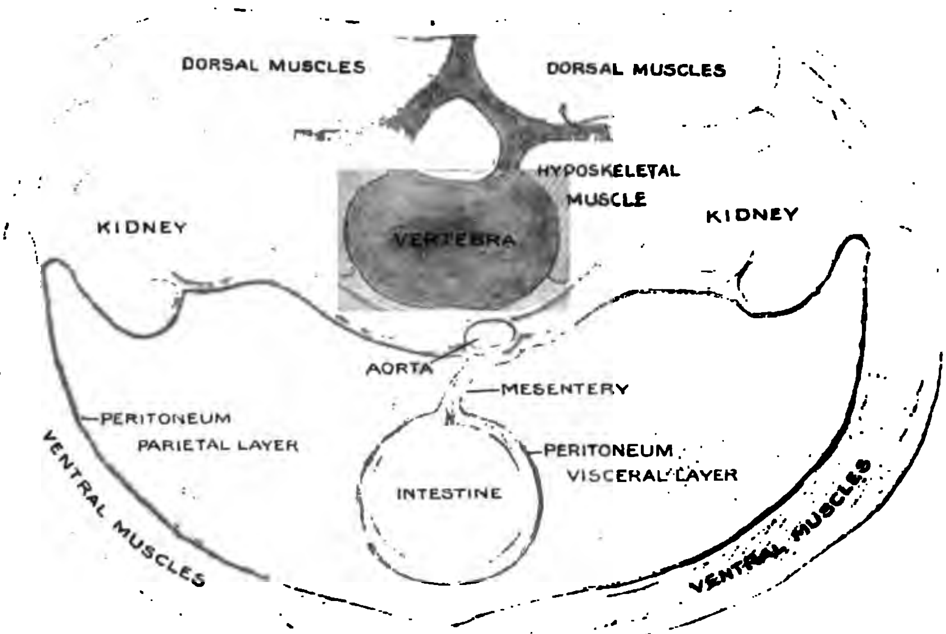
At the junction of the dorsal and ventral divisions of the mesoblast is a group of cells called the *intermediate cell mass*. This mass becomes segmented (corresponding to the somites) and

each segment, or *nephrotome*, gives rise to a portion of the *mesonephros*, the provisional kidney. Other cells of the mass become *mesenchyme*, which is converted into blood-vessels, connective tissue, etc.

As development proceeds, the metamerism of the muscles and arteries becomes more or less obscured, but that of the vertebræ and nerves is fully retained even in the adult. In the case of the muscle plates, from which all the voluntary musculature of the trunk is derived, great modifications occur. Extensive fusion of successive plates occurs, the intervening connective tissue disappearing more or less completely; associated with this fusion there is longitudinal and tangential splitting of the somites to form individual muscles; and portions of some of the plates may wander far from their original position. But notwithstanding these complicated changes, indications of the primary metameric arrangement of the muscle plates are abundant, and even in the most extreme cases of modification the developmental history of a muscle can be determined by means of its nerve supply. For the fibres derived from each plate will usually retain, no matter what changes of independence or position they may undergo, the innervation by their originally corresponding segmental nerve; so that the occurence in the lumbar region of the body of muscle-fibres (the diaphragm) supplied by nerve-fibres from a cervical nerve is evidence that the muscle-fibres have been derived from a cervical mesodermic somite and have subsequently migrated to the position they finally occupy.

As regards the arteries, they arise primarily from a longitudinal stem, the aorta, in a strictly segmental manner, each metamere having distributed to it two pairs of arteries and a single median one (fig. 20). One pair of arteries supplies the body wall, and these retain very distinctly their original metameric arrangement; the other pair passes to the paired viscera, such as the lungs, kidneys, ovaries (or testes), so many of the pairs disappearing, however, that their metameric arrangement is not very evident in the adult. The unpaired vessels supply the digestive tract and its unpaired appendages, such as the liver and pancreas, and undergo great modifications, those of the lower thoracic and lumbar regions becoming reduced by fusion and degeneration to three main trunks.

FIG. 20.—DIAGRAM OF A TRANSVERSE SECTION THROUGH THE ABDOMINAL REGION.



Branchiomerism.—Throughout the trunk and neck regions, then, a fundamental metameric plan underlies and determines the arrangement of many parts. In the head there is also evident a primary arrangement of the parts in succession; but this arrangement appears to be somewhat different from that of the trunk in that it involves the ventral instead of the dorsal mesoderm and is associated with the occurrence of branchial arches rather than with true mesodermic somites. It is consequently termed *branchiomerism*.

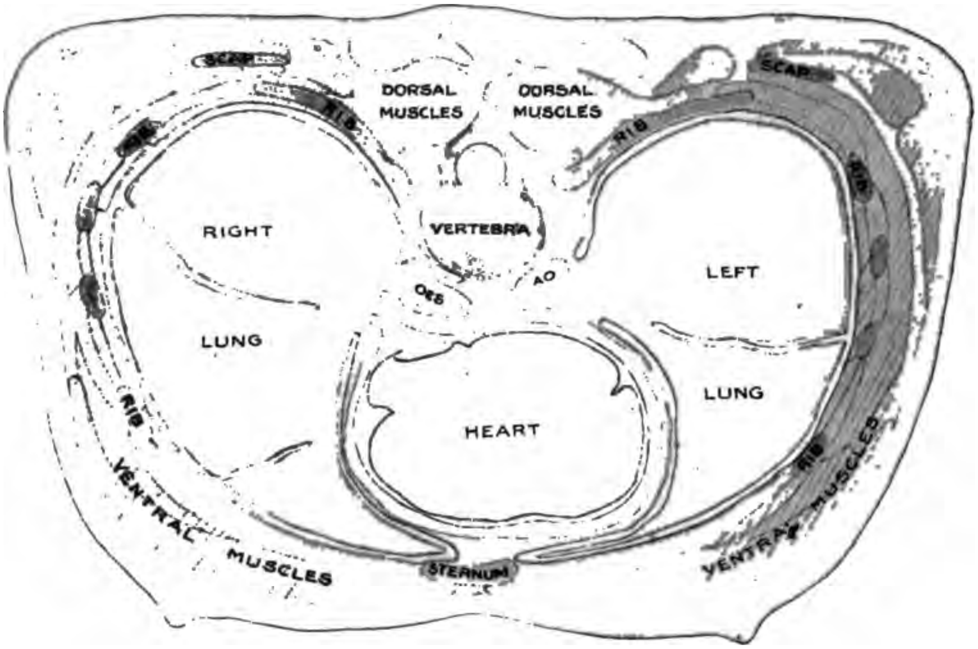
Not but that there are also indications of metamerism in the head, the muscles of the orbit, and the majority of the extrinsic muscles of the tongue, together with the nerves supplying these muscles, being apparently metameric structures, but the metamerism of this region of the body is largely overshadowed by the branchiomerism.

If an embryo of about the fifth week of development (fig. 22) be examined, there will be observed on the surface of the body in the pharyngeal region three or four linear depressions,

and sections will show that similar and corresponding grooves also occur upon the inner surface of the pharyngeal wall. These are the *branchial grooves*, and since they are four in number (with a rudimentary fifth) in the human embryo, they mark off five *branchial (or visceral) arches*, the first of which lies between the oral depression and the first branchial groove, while the fifth is situated behind the fourth groove. These branchial arches are so named because they represent the arches which (excepting the first) support the gills (branchiæ) in the lower vertebrates, the grooves representing the branchial slits, even although they do not become perforated in the human embryo.

Each *branchiomere* consists of an axial skeletal structure, of muscles which act on this skeleton, of a nerve which supplies the muscles and the neighbouring integument and mucous membrane, and of an artery which carries blood to all these structures. The arches, however, do not in the human embryo retain their original branchial function, but undergo extensive modifications, becoming adapted to various functions and showing less in the adult of their originally simple arrangement than do the metameres. Nevertheless no matter what modifications the musculature of any arch may undergo, it will retain its original innervation and, to a large extent, its relations to the skeletal elements of its arch; and even the arteries in their distribution show clear indications of being arranged in correspondence to the various arches.

FIG. 21.—DIAGRAM OF A TRANSVERSE SECTION THROUGH THE THORACIC REGION.
(The pleura is represented in blue and the pericardium in red.)



With respect to the fate of the various structures pertaining to each branchial arch, their general arrangement in the adult body may be stated in the following table:—

RELATIONS OF THE BRANCHIAL ARCHES IN THE ADULT

Arch	Skeleton	Muscles	Nerve
First arch.......	Mandible, malleus and incus.	Masticatory, mylohoid and digastric (ant.), tensor tympani.	Trigeminus.
Second arch.....	Hyoid (lesser cornu), styloid process and stapes.	Stylohyoid, digastric (post.), muscles of expression, stapedius.	Facialis.
Third arch......	Hyoid (greater cornu)...	Pharyngeal..................	Glossopharyngeus.
Fourth and fifth arches.	Thyreoid cartilage......	Pharyngeal and laryngeal.....	Vagus.

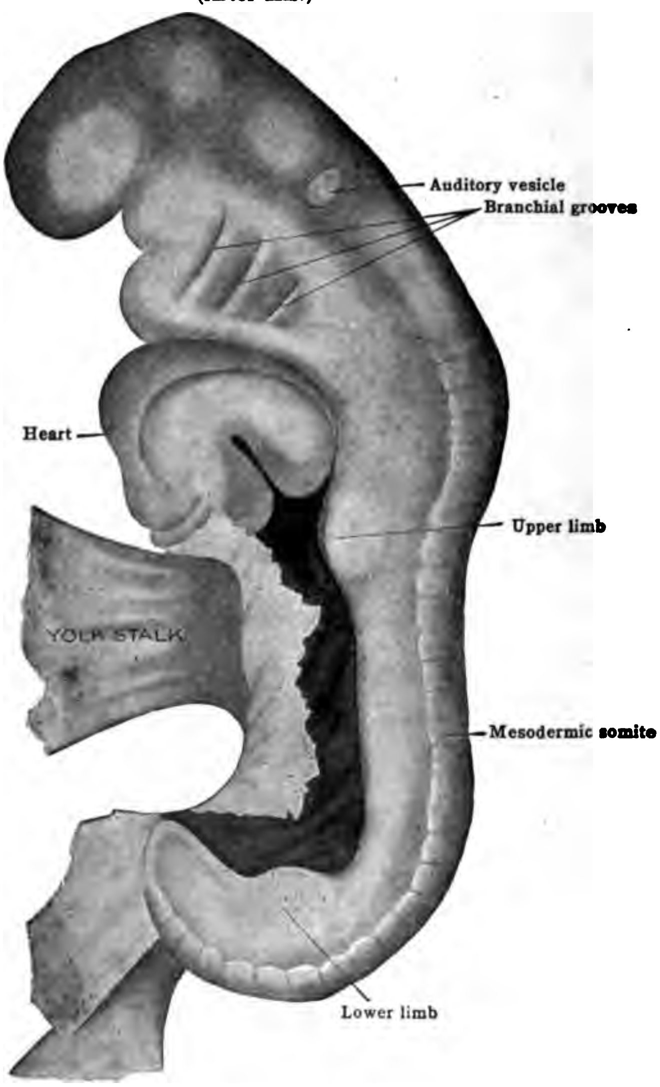
Branchial grooves.—Of the *external branchial grooves*, the first (lying between mandibular and hyoid arches) becomes deepened to form the *external auditory meatus*, the margins becoming elevated to form the *auricle* (fig. 26). The region corresponding to the second, third and fourth external grooves becomes depressed, forming the *sinus cervicalis*, which soon closes up and disappears.

The *internal branchial grooves* or pouches communicate with the pharyngeal cavity and are

lined with endoderm. The first internal groove becomes transformed into the ***auditory*** **(Eu stachian)** ***tube, tympanic cavity,*** **etc.** The second internal groove persists in part as the fossa o the *palatine tonsil.* The third and fourth grooves are probably represented in part by th *vallecula* and *recessus piriformis*, detached portions of their lining endoderm giving rise to th *thymus, parathyreoid glands*, etc. The rudimentary fifth groove is said to give rise to th *ultimobranchial body*, a structure of uncertain significance (fig. 27).

Development of the face.—The facial region is at first relatively small. It includes th sense organs (eye, ear, nose) and mouth region. Some of the more important developments features may be briefly mentioned. In an embryo of the sixth week (fig. 28) the wide mouth aperture is seen to be bounded below (posteriorly) by the lower (*mandibular*) portion of th

FIG. 22.—HUMAN EMBRYO OF 4.2 MM., SHOWING THREE BRANCHIAL GROOVES. (After His.)

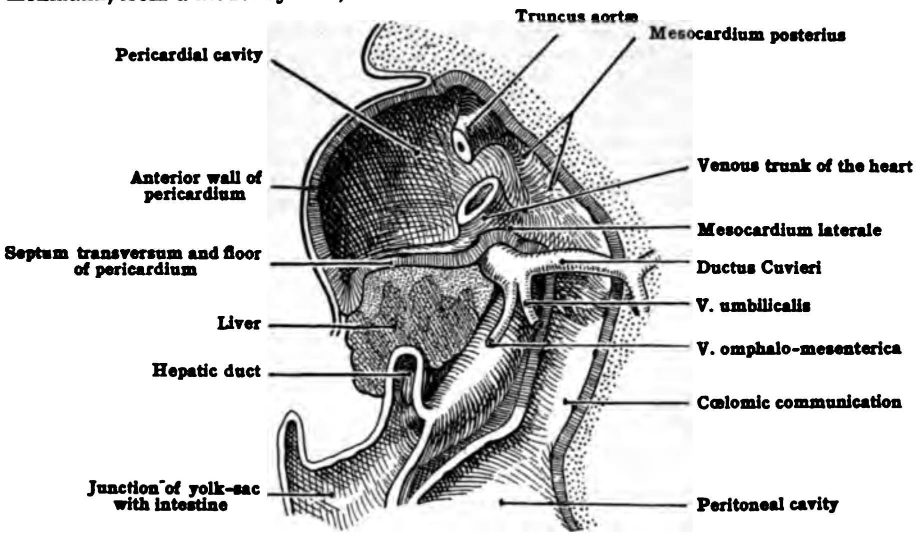


first arch, laterally by the upper (*maxillary*) process of the first arch. Above it is bounded by a median plate, the *nasal process*, which on either side forms a protuberance, the *globular process*. Lateral to the globular process is a rounded depression, the *nasal pit*. The maxillary process extends forward and fuses with the globular process to form the upper jaw region (failure to unite resulting in the malformation known as 'hare-lip'). The nose is at first broad, due to the width of the nasal process, which later becomes the nasal septum (fig. 29). The nasal pits deepen and later acquire openings into the primitive mouth cavity.

The viscera.—The structures so far considered belong, for the most part, to the body wall; it remains to consider the general plan of arrangement of the viscera. It has been pointed out that the body may be regarded as a cylinder enclosing two tubes, one of which constitutes the central nervous system and the

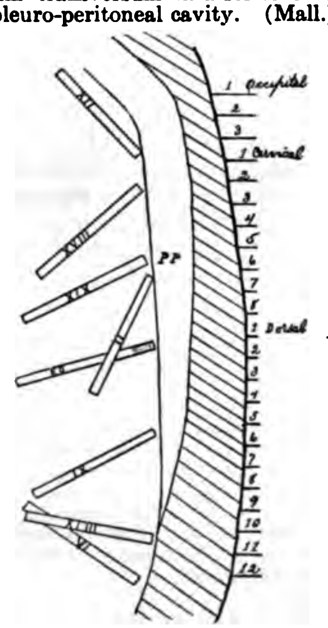
other the digestive tract. The latter may be regarded as being primarily a straight tube traversing lengthwise the body cavity enclosed by the body wall (figs. 18, 20). The layers of both the visceral and somatic plates which im-

FIG. 23.—SAGITTAL SECTION SHOWING THE PRIMITIVE PERICARDIAL AND CŒLOMIC COMMUNICATION, SEPTUM TRANSVERSUM, LIVER, ETC., IN A HUMAN EMBRYO OF 3 MM. (After Kollmann, from a model by His.)



mediately enclose the body cavity become transformed into a characteristic pleuro-peritoneal membrane. Near the mid-dorsal line, a vertical double plate of peritoneum extends ventrally connecting the somatic (parietal) and visceral layers of peritoneum, and constituting what is termed the *mesentery* (fig. 20).

FIG. 24.—DIAGRAM ILLUSTRATING THE RECESSION OF THE DIAPHRAGM (SEPTUM TRANSVERSUM) IN THE HUMAN EMBRYO. On the right are indicated the vertebral levels; on the left, the position of the septum transversum in a series of embryos from 2 mm. (XII) to 24 mm. (VI) in length. *pp*, pleuro-peritoneal cavity. (Mall.)

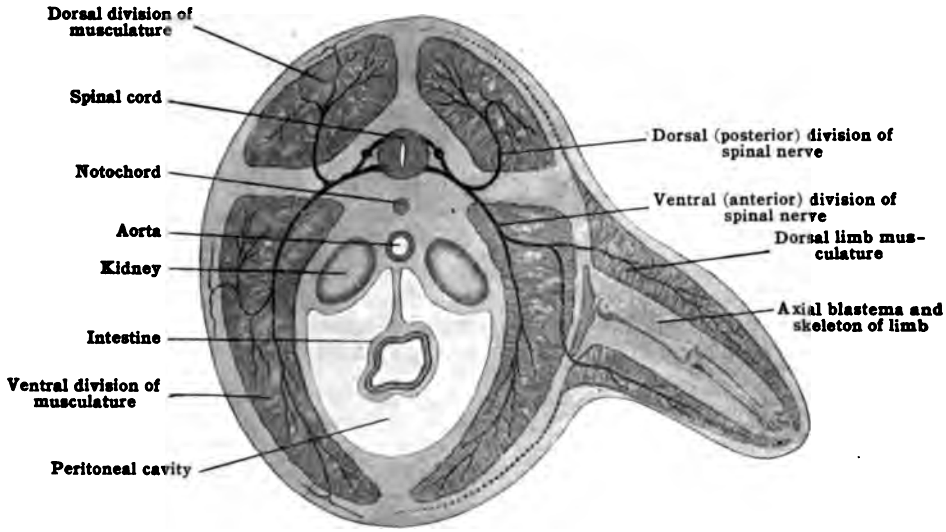


As development proceeds the digestive tract grows in length more rapidly than the cavity which contains it, and so gradually becomes thrown into numerous coils in the abdominal region, these changes leading to numerous modifications of the original arrangement of the mesentery. These will be described later on in the section on the digestive system. Several outgrowths also arise from the primitive digestive tract, to form important organs, such as the lungs,

the liver, the pancreas and the urinary bladder; and, with the exception of the bladder, each of these becomes completely invested by primitive peritoneum. In the case of the liver this original condition is practically retained, but the investment of the pancreas later becomes a partial one on account of the modifications which ensue in the mesentery. The bladder has only a portion of its surface in contact with the peritoneum, but the investment of the lungs remains complete, each lung, indeed, appropriating to itself the entire visceral layer of its half of the thorax, with the exception of a small ventral portion which forms the investment of the heart. Furthermore, the cavities which surround each of the three organs named, the two lungs and the heart, become completely separated from one another; and since each investment consists of a visceral and a parietal layer, each of the organs is enclosed within a double-walled sac, which in the case of each lung forms its *pleura*, while that of the heart is known as the *pericardium*. The spaces which occur within the thorax between the pleuræ of the two sides are known as the *mediastina*, which include the heart, œsophagus, etc. (fig 21).

In addition to the viscera mentioned there are some organs, such as the spleen and genito-urinary organs, which are developments of the mesoderm, the spleen arising in the mesentery which passes to the stomach and the genito-urinary organs primarily from the intermediate cell mass. The morphogeny of these structures and also of the vascular system, nervous system, and sense organs will be considered later in connection with their structure.

FIG. 25.—DIAGRAM OF A CROSS SECTION OF THE EMBRYONIC BODY AND LIMB. (McMurrich, after Kollman.)



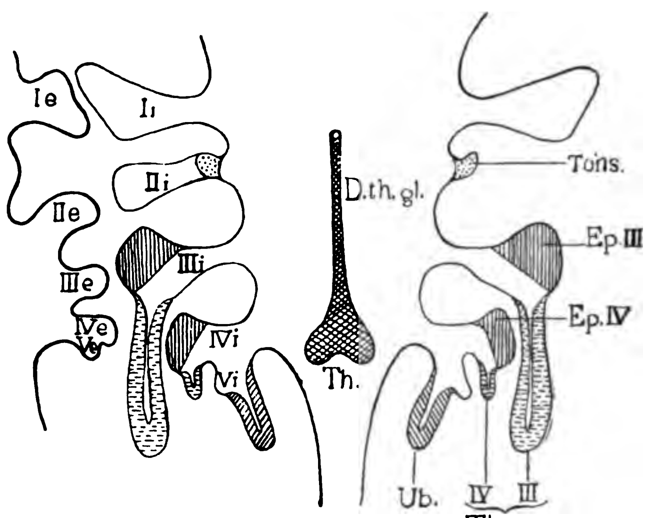
Recession of the diaphragm and heart.—In the early stages of development the heart is situated far forward, in what will eventually be the pharyngeal region (figs. 12, 17). Just behind (caudal to) the heart, between it and the yolk-sac, is a plate of connective tissue, the *septum transversum*, which serves for the passage of large veins from the body wall to the heart (figs. 17, 23). This septum together with certain accessory structures eventually gives rise to the diaphragm, which becomes a complete partition separating the thoracic and abdominal portions of the body cavity.

The diaphragm and heart are therefore originally situated far above (cranial to) their final position and recede in the course of development, producing an elongation of the vessels and nerves associated with them and forcing downward such organs as the stomach and liver (fig. 24). The chief factor in this displacement is probably the ventral head flexion and the precocious growth and expansion of the organs in the head region. The effects of this recession are especially noticeable in the nerves, these passing to the various organs concerned arising from a much higher level than that occupied by the organs. The nerve to the diaphragm, for instance, comes from the fourth cervical segment, those passing to the cardiac and pulmonary plexuses from the cervical region, and those to the plexus in relation with the stomach, liver and adjacent organs from the thoracic region. The blood-vessels, however, may shift their origins from the main trunks by successive anastomotic roots, so that in general they keep pace with the viscera in the migration caudalward.

The limbs.—Each limb at its first appearance (fig. 22) is a flat, plate-like outgrowth from the side of the body, and consists of an axial mass (blastema) of mesodermic tissue from which the limb skeleton will develop, and, surrounding this, a layer, also of mesodermic tissue, from which the muscles and blood-vessels will arise. It is as yet uncertain whether the muscle blastema is derived from the myotomes (as in lower vertebrates) or whether it develops from the mesenchyme.

FIG. 26.—LATERAL VIEW OF A HUMAN EMBRYO 18 MM. LONG, SHOWING THE DEVELOPMENT OF THE EXTREMITIES. M, mandibular arch.

FIG. 27.—DIAGRAM TO SHOW THE DERIVATIVES OF THE BRANCHIAL CLEFTS. *Ie*, II*e*, III*e*, IV*e*, V*e*, external branchial grooves. I*i*, II*i*, III*i*, IV*i*, V*i*, internal branchial grooves. Tons., palatine tonsil. *Ep III*, *Ep* IV, epithelial bodies. *Ub*, ultimobranchial body. *Th.*, thyreoid gland. *D.th. gl.*, ductus thyreoglossus. (Modified from Keibel and Mall.)



As the muscles become differentiated, nerves grow to them from a definite number of spinal segments (fig. 25).

At first each limb plate is so placed that one of its surfaces looks dorsally and the other ventrally, and one border (that corresponding to the thumb or great toe) is anterior (i. e., cranial) and the other posterior (caudal). Later, however, each limb becomes bent caudally through about ninety degrees, so that the limbs whose long axes were at first at right angles to the long axis of the body come to lie parallel to that axis. In addition there occurs a rotation of each fore-limb in such a manner that the thumb turns latero-dorsally, while in the lower limb the direction of the movement is exactly the opposite, the great toe turning ventro-medially. As a result there is an apparent reversal of the surfaces in the two limbs, the flexor muscles of the arm reaching on the surface which is directed anteriorly, while in the lower limb the corresponding muscles occupy the posterior surface. The dorsum of the foot and the great toe side correspond respectively to the back and thumb side of the hand, the tibia corresponds to the radius and the fibula to the ulna. The limb anlage soon becomes divided into three primary segments. The distal segment (hand or foot) is a flattened rounded disc, in which the digits soon appear (fig. 26). The proximal portion forms the forearm or leg and the arm or thigh. In general, the extremities follow the law of cranio-caudal and dorso-ventral (proximo-distal) development.

FIG. 28A.—FACE OF HUMAN EMBRYO OF ABOUT 8 MM. (His.)

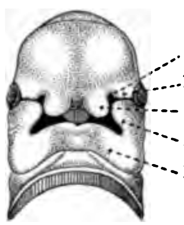


FIG. 28B.—FACE OF HUMAN EMBRYO AT STAGE SLIGHTLY LATER THAN 28A. (After Kallius.)

PRENATAL GROWTH IN LENGTH AND WEIGHT

Age in lunar months	Crown-rump or sitting height (Mall), cm.	Crown-heel or standing height (Mall), cm.	Weight at end of month, grams	Ratio of increase to weight at beginning of month
0	(diameter of ovum =0.2 mm.)	....	(Ovum = 0.000004 g.)	....
I	0.25	0.25	0.004	999.0
II	2.5	3.0	2.0	499.0
III	6.8	9.8	24.0	11.0
IV	12.1	18.0	120.0	4.0
V	16.7	25.0	330.0	1.75
VI	21.0	31.5	600.0	0.82
VII	24.5	37.1	1000.0	0.67
VIII	28.4	42.5	1600.0	0.60
IX	31.6	47.0	2400.0	0.50
*X	33.6	50.0	3200.0	0.33

Prenatal growth.—The prenatal growth of the human body in length and weight is indicated in the preceding table. According to Hasse, the age of the fœtus may be estimated from its total length as follows. Before the fifth month, the square of the age in (lunar) months gives the length in centimetres. After this, the age in months multiplied by five gives the length. This gives approximate results, except for the first month.

While the growth in *absolute* weight increases from month to month, it is important to note that the real (relative) growth rate rapidly diminishes. The ovum increases in weight during the first month about 1000 times, or 100,000 per cent. (not including the extra-embryonic structures). This rate diminishes rapidly, however, so that the increase during the last fœtal month is only about 33 per cent.

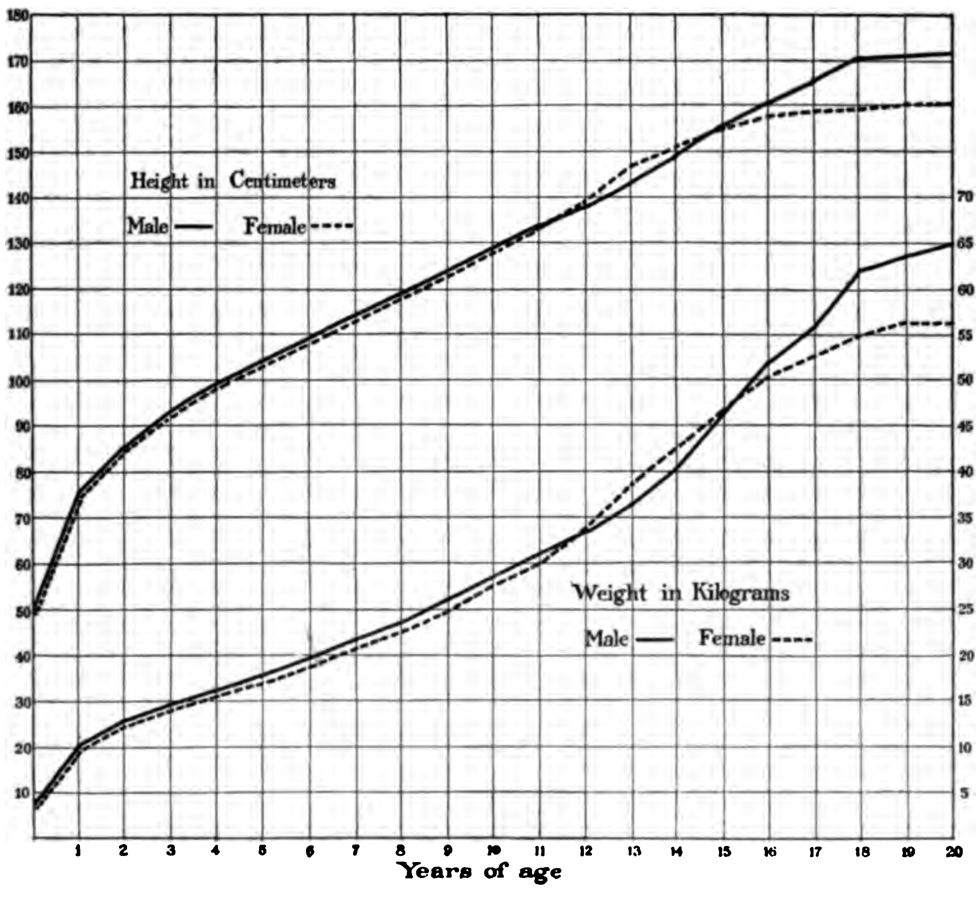
The continuation of growth in length and weight during the postnatal period is shown in the following chart (fig. 30).

The following chart is based upon data from Camerer (1–5 yrs.), Porter (6–17 yrs.), and Roberts (18–20 yrs.), showing the average postnatal growth in height and weight by sexes. The average height at birth is about 50 cm. (20 inches); weight, about 3200 g. (7 pounds). The male is slightly heavier and taller than the female, except during the acceleration at the period

* 270 days (Mall).

FIG. 29.—FACE OF A HUMAN EMBRYO AFTER COMPLETION OF THE UPPER JAW. (McMurrich from His.)

FIG. 30.—CHART SHOWING AVERAGE POSTNATAL GROWTH IN HEIGHT AND WEIGHT.



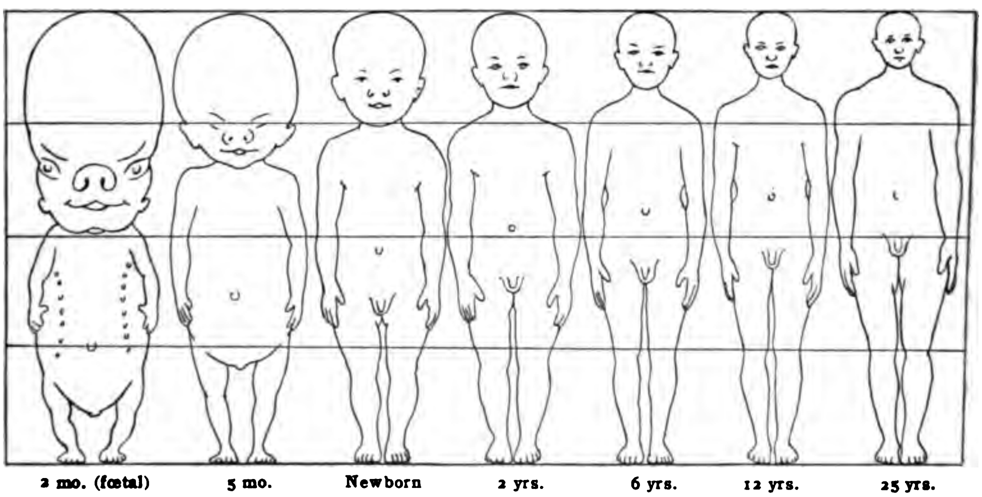
of puberty. Puberty occurs earlier in the female, so that between the ages of 12 and 15 the girls exceed the boys in average height and weight. With the exception of this period of acceleration, the (relative) growth rate in general diminishes steadily from birth, and has practically ceased at 20 years. The average height at this time is about 160 cm. (5 ft., 3 in.) in the female, and 170 cm. (5 ft., 7 in.) in the male; average weight, about 56 kilograms (126 lbs.) in the female, and 65 kilograms (146 lbs.) in the male. Under favourable conditions, growth in height may continue slowly up to about 25 years, and in weight even longer; but in old age there is a slight decrease in both height and weight.

The following measurements (from Holt, "Diseases of Infancy and Childhood" may be taken as a normal average standard of growth during the first three years. The weights are taken without clothing. The height is taken by placing the baby on a perfectly flat surface like a table, and having some one hold the child's knee down so that he lies out straight, then taking a tape-measure and measuring from the top of his head to the bottom of his foot, holding the tape line absolutely straight. The chest is measured by means of a tape line passed directly over the nipples around the child's body and midway between full inspiration and full expiration. The head measurement is taken directly around the circumference of the head, over the forehead and occipital bone.

		Weight, pounds	Height, inches	Chest, inches	Head, inches
Birth	Boys	7.55.	20.6	13.4	13.9
	Girls	7.16	20.5	13.0	13.5
6 months	Boys	16.0	25.4	16.5	17.0
	Girls	15.5	25.0	16.1	16.6
12 months	Boys	20.5	29.0	18.0	18.0
	Girls	19.8	28.7	17.4	17.6
18 months	Boys	22.8	30.0	18.5	18.5
	Girls	22.0	29.7	18.0	18.0
2 Years	Boys	26.5	32.5	19.0	18.9
	Girls	25.5	32.5	18.5	18.6
3 Years	Boys	31.2	35.0	20.1	19.3
	Girls	30.0	35.0	19.8	19.0

Relative growth of the parts.—The growth of the body is not uniform in the various parts, and changes in proportions therefore occur during development, as

FIG. 31.—FIGURES ILLUSTRATING THE CHANGES IN PROPORTION DURING PRENATAL AND POSTNATAL GROWTH. (STRATZ.)



shown in fig. 31. It will be noted that the changes are in accordance with the law of developmental direction previously explained, the growth impulse passing along the body in a cranio-caudal direction.

The *head* is therefore largest in the earlier stages, forming about half the body, decreasing to 25 per cent. in the newborn, and to 7 or 8 per cent. of the body in the adult. The *upper limbs* increase to about 10 per cent. of the body at birth, maintaining thereafter about the same relative size. The *trunk* as a whole remains of about the same relative size (about 45 per cent.),

although the thoracic portion reaches its maximum in the earlier stages, and the pelvic portion not until adult life. The *lower limbs*, like the pelvis, develop slowly, forming about 20 per cent. of the body at birth and reaching 35 per cent. in the adult.

Relative growth of the systems.—There is also a marked difference in the relative growth of the various systems. Data for the *skin* and *skeleton* are somewhat scanty and unsatisfactory. The *musculature*, however, is relatively small in the embryo, increasing to about 25 per cent. of the body in the newborn, and to 40 or 45 per cent. in the adult. The visceral group (including brain and spinal cord), on the other hand, is relatively largest in the early embryo, decreasing from about 35 per cent. of the body to about 24 per cent. in the newborn and to about 10 per cent. in the adult.

Relative growth of the organs.—While in general, the individual organs follow the course of relative growth of the visceral group, each organ has its own characteristic course of growth. As a rule, after its appearance in the embryo, each organ increases more or less rapidly to its maximum relative size, after which, although increasing in *absolute* size, it decreases in *relative* size through subsequent prenatal and postnatal life up to the adult.

Thus the *brain* in the embryo of the second month forms more than 20 per cent. of the body, but steadily declines to about 13 or 14 per cent. in the newborn, and about 2 per cent. in the adult. The *spinal cord* and *eyeballs* have a similar course of growth. The *heart* declines from about 5 per cent. of the body in the embryo of the second month to about .75 per cent. in the newborn and .46 per cent. in the adult. The *liver* decreases from a maximum of nearly 10 per cent. in the third month to 5 per cent. in the newborn and 2.7 per cent in the adult. The *suprarenal glands* decrease from about .46 per cent. of the body in the third month to .23 per cent. in the newborn and .01 per cent. in the adult. The *lungs* decrease from 3.3 per cent. in the fourth month to about 2 per cent. of the body at birth and 1 per cent. (bloodless weight) in the adult. The *kidneys* reach a maximum of about 1 per cent. of the body toward the end of the fœtal period, decreasing to about .46 per cent. in the adult. The *thymus, thyroid, spleen* and *alimentary canal* likewise reach their maximum slowly, being probably relatively largest about the time of birth. The *ovary* and *testis*, however, appear to be relatively largest during the prenatal period.

Variability.—It must be borne in mind that all statements concerning structure refer to the *average* or *norm*, and are always subject to variation. This is therefore a topic of importance to students of anatomy. Variations are classified as either *germinal* or *somatic*.

Germinal variations are due to fundamental differences in the germ plasm, and are transmitted by heredity. These include many of the characters whereby one individual differs from another. Variations according to sex are included under this class. Variations inherited from more or less remote ancestors are termed *atavistic* or *reversional*.

Somatic variations, or 'acquired characters,' are due to environmental influences, such as nutrition, temperature, shelter, disease, training, etc. While somatic variations may be very great, they do not affect the germ plasm and are not transmitted by heredity.

In many cases it is exceedingly difficult to distinguish germinal from somatic variations Size, for example, may be due to either or both. Moreover, somatic variations may be produced at any time after the fertilisation of the ovum. Very slight environmental changes are sometimes sufficient to produce a marked effect upon the delicately balanced mechanism of the developing embryo. Malformations and pathological conditions are thus often to be explained. As to the *extent* of variability, some characters are much more variable than others. Height, for example, is less variable than weight. Moreover, variability differs in the various parts and organs. In general, the head and head organs are less variable than the remainder of the body. The skeleton and musculature appear less variable than the integument and viscera.

Details concerning variations and methods for their measurement may be found in works on genetics and biometrical statistics.

References.—*Embryology:* Keibel and Mall, Human Embryology (2 vols.); Bryce, Quain's Anatomy, 11th ed., vol. 1; Minot, Laboratory Text-book of Embryology; McMurrich, Development of the Human Body. *Growth:* Minot, Age, Growth, and Death; Jackson, Amer. Jour. Anat., vol. 9; Anat. Record, vol. 3. *Heredity:* Davenport, Heredity and Eugenics; Walter, Genetics. *Biometry:* Davenport, Statistical Methods; Yule, Theory of Statistics.

SECTION II

OSTEOLOGY

REVISED FOR THE FIFTH EDITION

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THE SKELETON

THE skeleton forms the solid framework of the body, and is composed of bones, and in certain parts, of pieces of cartilage. The various bones and cartilages are united by means of ligaments, and are so arranged as to give the body definite shape, protect from injury the more important delicate organs, and afford attachment to the muscles by which the various movements are accomplished.

In its widest acceptance, the term skeleton includes all parts of the framework, whether internal or external, and as in many of the lower animals there are, in addition to the deeper osseous parts, hardened structures associated with the integument, it is convenient to refer to the two groups as endoskeleton and exoskeleton or dermal skeleton, respectively. All vertebrate—i. e., back-boned—animals possess an endoskeleton, and many of them a well-developed exoskeleton also, but in mammals, the highest group of vertebrates, the external skeleton, when it exists, plays a relatively subordinate part. In most of the invertebrates the endoskeleton is absent and the dermal skeleton alone is found.

In man by far the greater part of the endoskeleton is formed of bone, a tissue of definite chemical composition, being formed mainly of a gelatine basis strongly impregnated with lime salts.

The number of bones in the skeleton varies at different ages, some, which are originally quite independent, becoming united as age advances. They are arranged in an **axial set,** which includes the vertebral column, the skull, the ribs, and the sternum, and an **appendicular set,** belonging to the limbs. The following table shows the number of bones usually distinct in middle life, excluding the auditory ossicles:—

		BONES.
Axial Skeleton	The vertebral column	26
	The skull	23
	The ribs and sternum	25
Appendicular Skeleton	The upper limbs	64
	The lower limbs	62
	Total	200

Several of the skull bones are compound, i. e., in the immature skeleton they consist of separate elements which ultimately unite to form a single bone. In order to comprehend the nature of such bones it is advantageous to study them in the various stages through which they pass in the process of development in the fœtus and the child.

It follows, therefore, that to appreciate the **morphology** of the skeleton—i. e., the history of the osteological units of which it is composed—the **osteogenesis** or mode of development of the bones must be studied, as well as their **topography** or position.

Some bones arise by **ossification in membrane,** others in **cartilage.** In the embryo, many portions of the skeleton are represented by cartilage which may become infiltrated by lime salts —**calcification.** This earthy material is taken up and redeposited in a regular manner— **ossification.** Portions of the original cartilage persist at the articular ends of bones, and, in

young bones, at the **epiphysial** lines, i. e., the lines of junction of the main part of a bone with the extremities or epiphyses. Long bones increase in length at the **epiphysial cartilages**, and increase in thickness by ossification of the deeper layers of the investing membrane or **periosteum**. These processes—intracartilaginous and intramembranous ossification—proceed concurrently in the limb-bones of a young and growing mammal.

There is no bone in the human skeleton which, though pre-formed in cartilage, is perfected in this tissue. The ossification is completed in membrane. On the other hand, there are numerous instances in the skull, of bones the ossification of which begins in, and is perfected by, the intramembranous method. Ossification in a few instances commences in membrane, but later invades tracts of cartilage; occasionally the process begins in the **perichondrium** and remains restricted to it, never invading the underlying cartilage, which gradually disappears as the result of continued pressure exerted upon it by the growing bone. The vomer and nasal bones are the best examples of this mode of development. Further details of development and ossification are included in the description of each bone.

The **limb-bones** differ in several important particulars from those of the skull. Some of the long bones have many centres of ossification, but these have not the same significance as those of the skull. It is convenient to group the centres into two sets, **primary** and **secondary**. The primary nucleus of a long bone appears quite early in fœtal life, and the main part (shaft) thus formed is called the **diaphysis**. In only three instances does a secondary centre appear before birth, e. g., the lower end of the femur, the head of the tibia, and occasionally the head of the humerus. Many primary ossific nuclei appear after birth, e. g., those for the carpal bones, the cuneiform and navicular bones of the foot, the coracoid process of the scapula, and for the third, fourth, and fifth pieces of the sternum.

When a bone ossifies from one nucleus only, this nucleus may appear before or after birth. Examples: the talus (astragalus) at the seventh month of fœtal life, and the lesser multangular (trapezoid) at the eighth year. When a bone possesses one or more secondary centres, the primary nucleus, as a rule, appears early. Examples: the femur, humerus, phalanges, and the calcaneus.

Secondary centres which remain for a time distinct from the main portion of a bone are termed **epiphyses**. An epiphysis may arise from a single nucleus, as is the case at the lower end of the femur, or from several, as at the upper end of the humerus. Prominences about the ends of long bones may be capped by separate epiphyses, as illustrated at the upper end of the femur.

According to Professor F. G. Parsons, there are at least three kinds of epiphyses:—(1) Those which appear at the articular ends of long bones, which, since they transmit the weight of the body from bone to bone, may be termed *pressure* epiphyses. (2) Those which appear as knob-like processes, where important muscles are attached to bones; and as these are concerned with the pull of muscles, they may be described as *traction* epiphyses. (3) The third kind includes those epiphyses which represent parts of the skeleton at one time of functional importance but which, having lost their function, have now become fused with neighbouring bones and only appear as separate ossifications in early life. These may be termed *atavistic* epiphyses and include such epiphyses as the tuberosity of the ischium, the representative of the hypoischium of reptiles.

The epiphyses of bones seem to follow certain rules, thus:—

1. Those epiphyses whose centres of ossification appear last are the first to unite with the shaft. There is one exception, however, to this statement, viz., the upper end of the fibula, which is the last to unite with the shaft, although its centre appears two years after that for the lower end. This may perhaps be accounted for by the rudimentary nature of the proximal end of the fibula in man and many other mammals.

2. The epiphysis toward which the nutrient artery is directed is the first to be united with the shaft. It is also found that while the increase in length of the long bones takes place at the epiphysial cartilages, the growth takes place more rapidly and is continued for a longer period at the end where the epiphysis is the last to unite. It follows, therefore, that the shifting of the investing periosteum, which results from these two factors, leads to obliquity of the vascular canal by drawing the proximal portion of the nutrient artery toward the more rapidly growing end. Moreover, when a bone has only one epiphysis, the nutrient artery will be directed toward the extremity which has no epiphysis.

3. The centres of ossification appear earliest in those epiphyses which bear the largest relative proportion to the shafts of the bones to which they belong.

4. When an epiphysis ossifies from more than one centre, the various nuclei coalesce before the shaft and epiphysis consolidate, e. g., the upper end of the humerus.

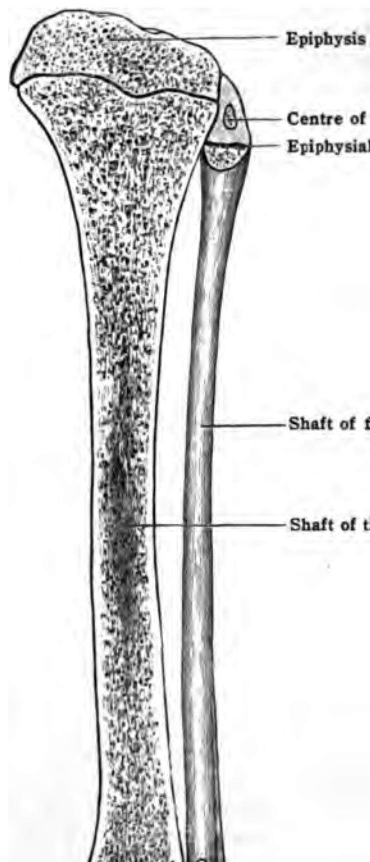
On section, the shaft of a fœtal long bone is seen to be occupied by red marrow lodged in bony cells which do not present any definite arrangement. In an adult the central portion of the shaft is filled with fat or marrow held together by a delicate reticulum of connective tissue, whence the space is known as the **medullary cavity**. The expanded ends of the bones contain a network of cancellous tissue, the intervals being filled with red marrow. This cancellous tissue differs from that of the fœtal bone in being arranged in a definite manner according to the direction of pressure exerted by the weight of the body, and the tension produced by the muscles. The arrangement of the cancelli in consequence of the mechanical conditions to which bones are subject is noticed in the description of a vertebra, the femur, and the humerus.

Bones are divisible into four classes:—**long, short, flat,** and **irregular.** The **long bones,** found chiefly in the limbs, form a system of levers sustaining the weight of the trunk and providing the means of locomotion. The **short bones,** illustrated by those of the carpus and tarsus, are found mainly where compactness, elasticity, and limited motion are the principal requirements. **Flat bones** confer protection or provide broad surfaces for muscular attachment, as in the case of the cranial bones and the shoulder-blade. Lastly, the **irregular** or **mixed bones** constitute a group of peculiar form, often very complex, which cannot be included under either of the preceding heads. These are the vertebræ, sacrum, coccyx, and many of the bones of the skull.

The **shafts** of long bones at the time of birth are mainly cylindrical and free from ridges. The majority of the lines and ridges so conspicuous on the shafts of long bones in adults are due to the ossification of muscle-attachments. The more developed the muscles, the better marked the ridges become.

The surfaces of bones are variously modified by environing conditions. Pressure at the extremities causes enlargement, and movement renders them smooth. The two causes combined produce an articular surface. When rounded and supported upon a constricted portion of bone, an articular surface is termed a **head**, sometimes a **condyle**; when depressed, a **glenoid fossa**. Blunt, non-articular processes are called **tuberosities**; smaller ones, **tubercles**; sharp projections, **spines**. Slightly elevated ridges of bones are **crests**; when narrow and pronounced, **lines** and

FIG. 32.—THE TIBIA AND FIBULA IN SECTION TO SHOW THE EPIPHYSES.



borders. A shallow depression is a **fossa**; when narrow and deep, a **groove**; a perforation is usually called a **foramen.**

In addition to these, other terms are employed which do not require any explanation, such as **canal, notch** or **incisura, sulcus** or **furrow**, and the like.

I. THE AXIAL SKELETON

A. THE VERTEBRAL COLUMN

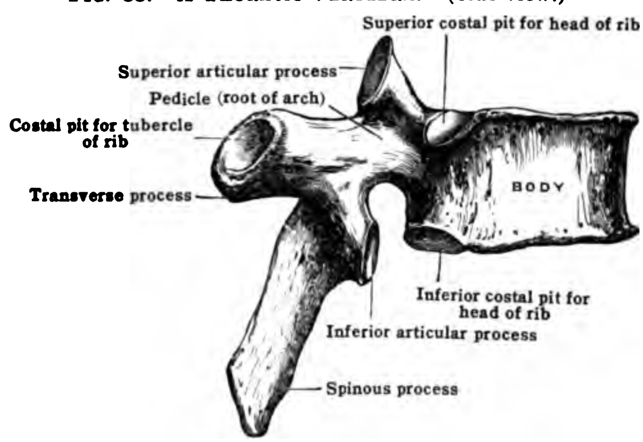
The **vertebral column** [columna vertebralis] consists of a series of bones called **vertebræ,** closely connected by means of fibrous and elastic structures, which allow of a certain but limited amount of motion between them. In the young

subject the vertebræ are thirty-three in number. Of these, the upper twenty-four remain separate throughout life, and are distinguished as **movable** or **true vertebræ.** The succeeding five vertebræ become consolidated in the adult to form one mass, called the **sacrum,** and at the terminal part of the column are four rudimentary vertebræ, which also tend to become united as age advances, to form the **coccyx.** The lower nine vertebræ thus lose their mobility as individual bones, and are accordingly known as the **fixed** or **false vertebræ.** Of the true vertebræ, the first seven are called **cervical** [cervicales], the succeeding twelve **thoracic** [thoracales] or **dorsal,** and the remaining five **lumbar** [lumbales].

Although the vertebræ of the different regions of the column differ markedly in many respects, each vertebra is constructed on a common plan, which is more or less modified in different regions to meet special requirements. The essential characters are well seen in the vertebræ near the middle of the thoracic region, and it will be advantageous to commence the study of the vertebral structures with one selected from this region.

Description of a thoracic vertebra (figs. 33, 34).—The vertebra consists of two essential parts—a body in front and an arch behind.

FIG. 33.—A THORACIC VERTEBRA. (Side view.)



The **body** [corpus vertebræ] or **centrum** is a solid disc of bone, somewhat heart-shaped, deeper behind than in front, slightly concave on its superior and inferior surfaces, and wider transversely than antero-posteriorly. The upper and lower surfaces are rough for the intervertebral discs which are interposed between the bodies of the vertebræ, and the margins are slightly lipped. The circumference of the body is concave from above downward in front, convex fron side to side, and perforated by numerous vascular foramina. Posteriorly it is concave from side to side and presents one or two large foramina for the exit of veins from the cancellous tissue. On each side of the body, at the place where it joins the arch, are two costal pits (superior and inferior) [fovea costalis superior; inferior] placed at the upper and lower borders, and when two vertebræ are superimposed, the adjacent costal pits form a complete articular pit for the head of a rib. The superior and inferior costal pits were formerly designated as "demi-facets."

The **arch** [arcus vertebræ] is formed by two pedicles and two laminæ, and supports seven processes—one spinous, two transverse, and four articular. The pedicles or **roots** of the vertebral arch [radices arcus vertebræ] are two short, constricted columns of bone, projecting horizontally backward from the posterior surface of the body. The concavities on the upper and lower borders of each pedicle, of which the lower is much the deeper, are named **vertebral notches** [incisurae], and when two vertebræ are in position, the notches are converted into **intervertebral foramina** for the transmission of the spinal nerves and blood-vessels.

The **laminæ** are two broad plates of bone which connect the spinous process with the roots (pedicles) and complete the arch posteriorly. The superior border and the lower part of the anterior surface of each lamina is rough for the insertion of the ligamenta flava. The upper part of the anterior surface is smooth where it forms the posterior boundary of the vertebral canal. When articulated, the

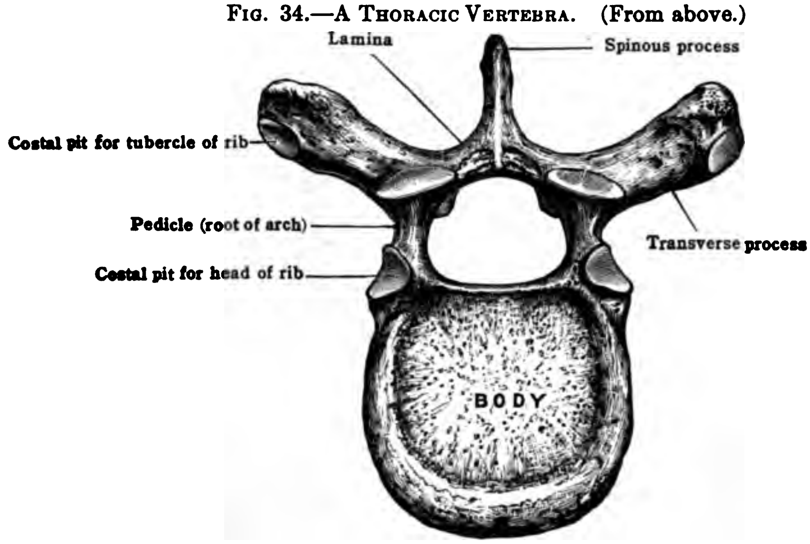
laminæ in the thoracic region are imbricated or sloped, one pair over the other, somewhat like tiles on a roof.

The **spinous process** [processus spinosus], long and three-sided, projects backward and downward from the centre of the arch and terminates in a slight tubercle. It gives attachment by its prominent borders to the interspinous ligaments and by its free extremity to the supraspinous ligament. It serves mainly as a process for muscular attachment.

The **transverse processes** [processus transversus] are two in number and extend laterally from the arch at the junction of the pedicles and laminæ. They are long, thick, backwardly directed columns of bone terminating in a clubbed extremity, on each of which is a costal pit for articulation with the tubercle of a rib. The transverse processes, in addition to supporting the ribs, afford powerful leverage to muscles.

The **articular processes,** two superior and two inferior, project upward and downward opposite the attachments of the transverse processes. The superior are flat and bear facets or surfaces [facies articulares superiores] which are directed

FIG. 34.—A THORACIC VERTEBRA. (From above.)



upward, backward, and laterally, and are situated a little in advance of the inferior, the facets of which [facies articulares inferiores] are oval, concave, and directed downward, forward, and medially.

The **vertebral foramen** is bounded anteriorly by the body, posteriorly and on each side by the arch. It is nearly circular, and is smaller than in the cervical or the lumbar region. When the vertebræ are articulated, the series of rings constitute the **spinal** or **vertebral** canal [canalis vertebralis], in which is lodged the **spinal cord.**

THE CERVICAL VERTEBRÆ

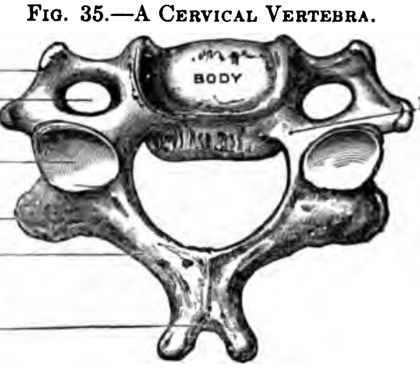
A typical cervical vertebra (from the third to the sixth inclusive) presents the following characteristics (fig. 35):—The **body** is smaller than in other regions of the column and is of oval shape with the long axis transverse. The lateral margins of the upper surface are raised into prominent lips, so that the surface is concave from side to side; it is also sloped downward in front. The inferior surface, on the contrary, projects downward in front and is rounded off at the sides to receive the corresponding lips of the adjacent vertebra. It is concave antero-posteriorly and convex in an opposite direction.

The **roots** (pedicles) are directed laterally and backward and spring from the body about midway between the upper and lower borders. The superior and inferior notches are nearly equal in depth, but the inferior are usually somewhat deeper. The **laminæ** are long, narrow, and slender. The **spinous process** is short and bifid at the free extremity.

Articular processes.—Both the superior and inferior articular processes are situated at the junction of the root with the lamina and they form the upper and lower extremities of a small column of bone. The articular surfaces are oblique and nearly flat, the superior looking backward and upward, and the inferior forward and downward.

The **transverse process** presents near its base a round **costo-transverse foramen** [foramen transversarium] for the transmission of the vertebral artery, vein, and a plexus of sympathetic nerves. Moreover, each process is deeply grooved above for a spinal nerve, and is bifid at its free extremity, terminating in two tubercles—anterior and posterior. The **costo-transverse foramen** is very characteristic of a cervical vertebra. It is bounded medially by the pedicle, posteriorly by the transverse process (which corresponds to the transverse process of a thoracic vertebra), anteriorly by the costal process (which corresponds to the rib in the thoracic region), and laterally by the costo-transverse lamella. The latter is a bar of bone joining the two processes and directed obliquely upward and forward in the upper vertebræ and horizontally in the lower. The **vertebral foramen** is triangular with rounded angles, and is larger than in the thoracic or lumbra vertebræ.

FIG. 35.—A CERVICAL VERTEBRA.



Peculiar cervical vertebræ.—The various cervical vertebræ possess distinguishing features, though, with the exception of the first, second, and seventh, which are so different as to necessitate separate descriptions, these are largely confined to the direction of the costo-transverse lamella, and the size and level of the anterior and posterior tubercles. In the third the anterior tubercle is higher than the posterior and the costo-transverse lamella is oblique; in the fourth the anterior tubercle is elongated vertically, so that its lower end is nearly on a level with the posterior, though the lamella still remains oblique. In the fifth and sixth they are nearly on the same level, but in the latter the anterior tubercle is markedly developed to form the **carotid tubercle.**

THE ATLAS OR FIRST CERVICAL VERTEBRA

This vertebra (fig. 36) is remarkable in that it has neither body nor spinous process. It has the form of an irregular ring, and consists of two thick portions, the **lateral masses,** united in front and behind by bony arches. The **anterior arch** joins the lateral masses in front and constitutes about one-fifth of the entire circumference of the ring. On its anterior surface it presents a **tubercle** for the attachment of the *longus colli* muscle and the anterior longitudinal ligament, and on its posterior surface a circular facet [fovea dentis] for articulation with the odontoid process [dens] of the axis. The upper and lower borders serve for the attachment of ligaments uniting the atlas to the occipital bone and axis respectively.

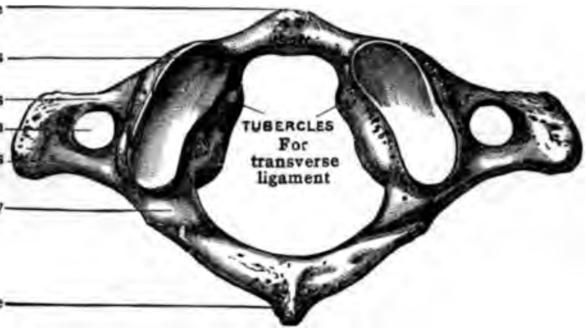
The **lateral masses** are thick and strong, supporting the articular processes above and below and extending laterally into the transverse processes. The superior articular surfaces are elongated, deeply concave, and converge in front. Directed upward and medially they receive the condyles of the occipital bone, and occasionally each presents two oval facets united by an isthmus. The inferior articular surfaces are circular and almost flat; they are directed downward and medially and articulate with the axis. The articular processes, like the superior articular processes of the axis, differ from those of other vertebræ in being situated in front of the places of exit of the spinal nerves.

Between the upper and lower articular surfaces on the inside of the ring are two smooth rounded **tubercles,** one on each side, to which the transverse ligament is attached. This liga-

ment divides the interior of the ring into a smaller anterior part for the dens of the axis, and a larger posterior part, corresponding to the foramina of other vertebræ, for the spinal cord and its membranes.

The **transverse processes** are large and extend farther outward than those of the vertebræ immediately below. They are flattened from above downward and each is perforated by a large **costo-transverse** foramen; the extremity is not bifid, but, on the contrary, is broad and rough for the attachment of numerous muscles. The **posterior arch** unites the lateral masses behind and forms about two-fifths of the entire circumference. It presents in the middle line a rough elevation or tubercle representing a rudimentary spinous process. At its junction with the lateral mass on the superior surface is a deep **groove**, the **sulcus arteriæ vertebralis**, which

FIG. 36.—THE FIRST CERVICAL VERTEBRA OR ATLAS.

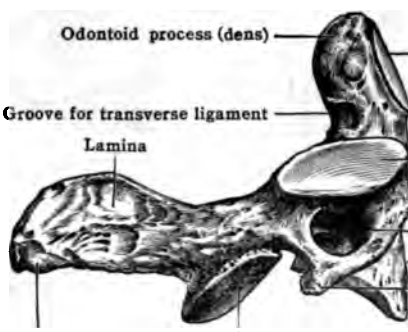


lodges the vertebral artery and the sub-occipital (first spinal) nerve. The groove corresponds to the superior notches of other vertebræ and occasionally it is converted into a foramen by a bony arch—the ossified oblique ligament of the atlas. A similar but much shallower notch is present on the inferior surface of the posterior arch, and, with a corresponding notch on the axis, forms an intervertebral foramen for the exit of the second spinal nerve. The upper and lower surfaces of the arch afford attachment to ligaments uniting the atlas to the occipital bone and the axis.

The atlas gives attachment to the following muscles:—

Anterior arch...............	Longus colli.
Posterior arch...............	Rectus capitis posterior minor.
Transverse process..........	Rectus capitis anterior (minor), rectus capitis lateralis, obliquus capitis inferior, obliquus capitis superior, splenius cervicis, levator scapulæ, and intertransversarii, anterior and posterior.

FIG. 37.—THE EPISTROPHEUS OR AXIS.



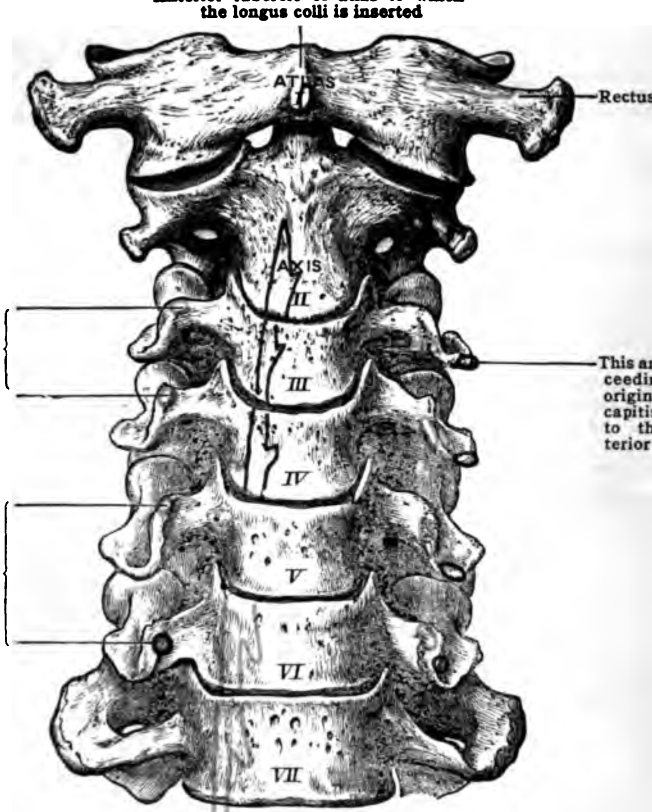
THE EPISTROPHEUS (AXIS)

The **epistropheus** (axis) (fig. 37) is the thickest and strongest of the bones of this region, and is so named from forming a pivot on which the atlas rotates, carrying the head. It is easily recognised by the rounded **dens** (odontoid process) which surmounts the upper surface of the **body.** This process, which represents the displaced body of the atlas, is large, blunt, and tooth-like, and bears on its anterior surface an oval facet for articulation with the anterior arch of the atlas; posteriorly it presents a smooth groove which receives the transverse ligament. To the apex a thin narrow fibrous band (the apical dental ligament) is attached, and on each side of the apex is a rough surface for the attachment of the alar

ligaments which connect it with the occipital bone. The enlarged part of the process is sometimes termed the **head,** and the constricted basal part the **neck.** The inferior surface of the body resembles that of the succeeding vertebræ and is concave from front to back and slightly convex from side to side. Its anterior surface is marked by a median ridge separating two lateral depressions for the insertion of the *longus colli.*

The **roots** (pedicles) are stout and broad; the **laminæ** are thick and prismatic; the **spinous process** is large and strong, deeply concave on its under surface, and markedly bifid; the **transverse processes** are small, not bifurcated and not grooved. The costo-transverse foramen is directed very obliquely upward and laterally and the costal process is larger than the transverse.

FIG. 38.—THE CERVICAL VERTEBRÆ. (Anterior view.)



The **superior articular surfaces** are oval, and directed upward and laterally for articulation with the atlas. They are remarkable in being supported partly by the body, and partly by the pedicles, and in being situated in front of the superior notches. The **inferior articular surfaces** are similar in form and position to those of the succeeding vertebræ.

The axis gives attachment to the following muscles:—

Body	Longus colli.
Spinous process	Obliquus capitis inferior, rectus capitis posterior major semispinalis cervicis, interspinales, multifidus.
Transverse process	Splenius cervicis, intertransversarii, levator scapulæ, longissimus (transversalis) cervicis, scalenus medius.

THE SEVENTH CERVICAL VERTEBRA

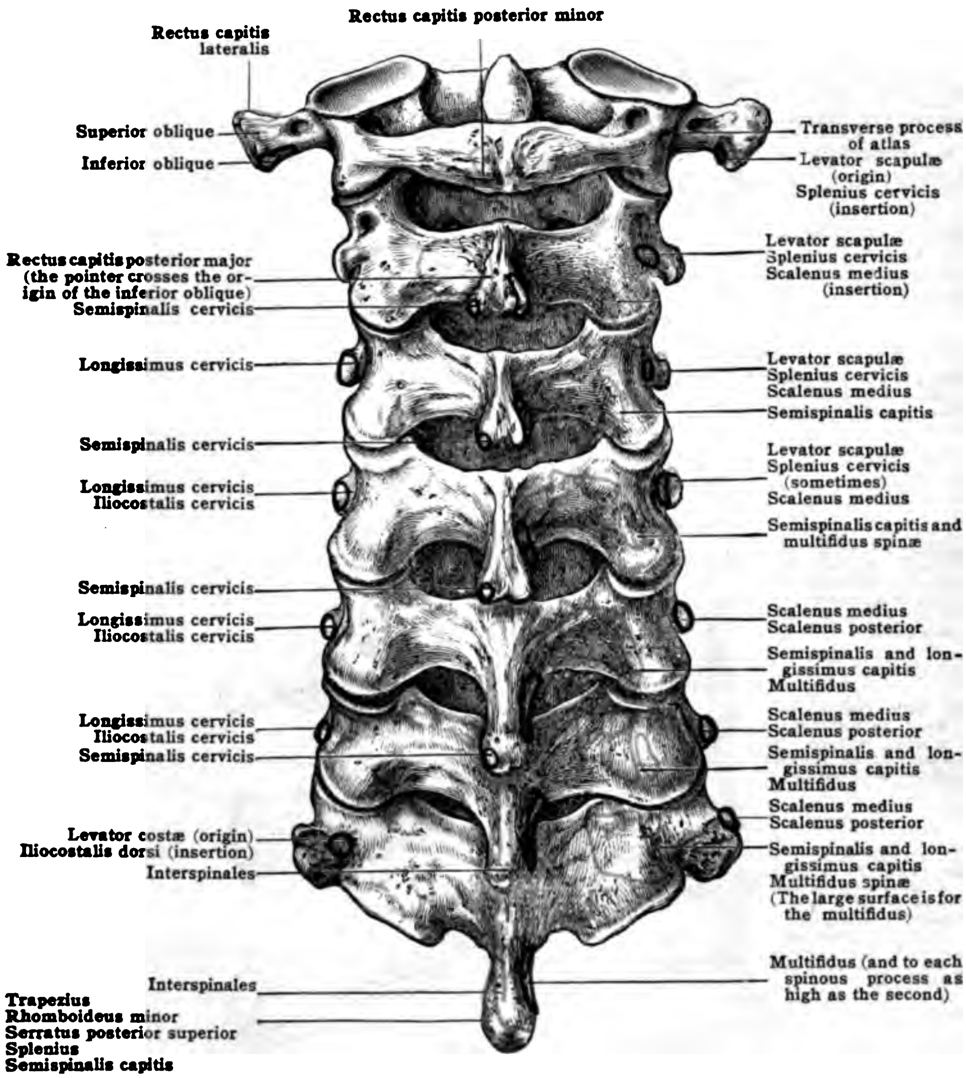
Situated at the junction of the cervical and thoracic regions of the vertebral column, the seventh cervical vertebra (figs. 38, 39) may be described as a transitional vertebra—i. e., possessing certain features characteristic of both regions.

The **spinous process** is longer than that of any of the other cervical vertebræ. It is not bifurcated, but ends in a broad tubercle projecting beneath the skin,

whence the name **vertebra prominens** has been applied to this bone. The **transverse process** is massive; the costal element of the process is very small, but, on the other hand, the posterior or vertebral part of the process is large and becoming more like the transverse process of a thoracic vertebra.

The costo-transverse foramen is the smallest of the series and may be absent. It does not, as a rule, transmit the vertebral artery, but frequently gives passage to a vein. Occasionally the costal process is segmented off and constitutes a cervical rib. The body sometimes bears on each side near the lower border a costal pit for the head of the first rib. When this is present, there is usually a well-developed cervical rib.

FIG. 39.—THE CERVICAL VERTEBRÆ. (Posterior view.)



The seventh cervical vertebra gives attachment to the following muscles:—

Body	Longus colli.
Spinous process	Trapezius, rhomboideus minor, serratus posterior superior, splenius capitis, multifidus, interspinales, semispinalis dorsi.
Transverse process	Intertransversarii, levator costæ, scalenus posterior, iliocostalis dorsi (musculus accessorius), scalenus medius, semispinalis capitis (complexus).
Articular process	Multifidus, longissimus capitis (trachelomastoid).

The cervical vertebræ exhibit great variation in regard to the extremities of their spinous processes. As a rule among Europeans, the second, third, fourth, and fifth vertebræ possess bifid spines. The sixth and seventh exhibit a tendency to bifurcate, their tips presenting two small lateral tubercles; sometimes the sixth has a bifid spine, and more rarely the seventh pre-

sents the same condition. Occasionally all the cervical spines, with the exception of the second, are non-bifid, and even in the axis the bifurcation is not extensive. In the lower races of men the cervical spines are relatively shorter and more stunted than in Europeans generally and, as a rule, are simple. The only cervical vertebra which presents a bifid spine in all races is the axis; even this may be non-bifid in the Negro, and occasionally in the European. (Owen, Turner, Cunningham.)

The laminæ of the lower cervical vertebræ frequently present posteriorly distinct tubercles from which fasciculi of the *multifidus* muscle arise. They are usually confined to the sixth and seventh vertebræ, but are fairly frequent on the fifth, and are occasionally seen on the fourth.

FIG. 40.—PECULIAR THORACIC VERTEBRÆ.

THE THORACIC VERTEBRÆ

The general characters of the thoracic (or dorsal) vertebræ have already been considered. Their most distinguishing features are the **pits on the transverse processes** and sides of the **bodies** for the **tubercles** and **heads of the ribs** respectively.

Peculiar thoracic vertebræ.—Several vertebræ in this series differ from the typical example. The exceptional ones are—the **first, ninth, tenth, eleventh,** and **twelfth (fig. 40).**

The **first** thoracic vertebra is a transitional vertebra. The **body** in its general conformation approaches very closely the seventh cervical, in that the greatest diameter is transverse, its upper surface is concave from side to side, and its lateral margins bear two prominent lips. On each side is an entire pit, close to the upper border, for the head of the first rib, and a very small pit (inferior costal pit) below for the head of the second rib. The **spinous process** is thick, strong, almost horizontal and usually more prominent than that of the seventh cervical, an important point to remember when counting the spines in the living subject. Occasionally the transverse process is perforated near the root.

The **ninth** has superior costal pits, and usually no inferior; when the inferior pits are present, this vertebra is not exceptional.

The **tenth** usually has an entire costal pit at its upper border, on each side, but occasionally only a superior costal pit. It has no lower pits and the pits on the transverse processes are usually small.

The **eleventh** has a large body resembling a lumbar vertebra. The pits are on the pedicles and they are complete and of large size. The transverse processes are short, show evidence of becoming broken up into three parts, and have no pits for the tubercles of the eleventh pair of ribs.

In many mammals, the spines of the anterior vertebræ are directed backward, and those of the posterior directed forward, whilst in the centre of the column there is usually one spine vertical. The latter is called the anti-clinal vertebra, and indicates the point at which the thoracic begin to assume the characters of lumbar vertebræ. In man the eleventh thoracic is the anti-clinal vertebra.

The **twelfth** resembles in general characters the eleventh, but may be distinguished from it by the articular surfaces on the inferior articular processes being convex and turned laterally as in the lumbar vertebræ. The transverse process is rudimentary and tripartite, presenting for examination three tubercles, *superior*, *inferior*, and *lateral*, which correspond respectively to the mammillary, accessory, and transverse processes of the lumbar vertebra. There is one complete pit on the root (pedicle) for the head of the twelfth rib.

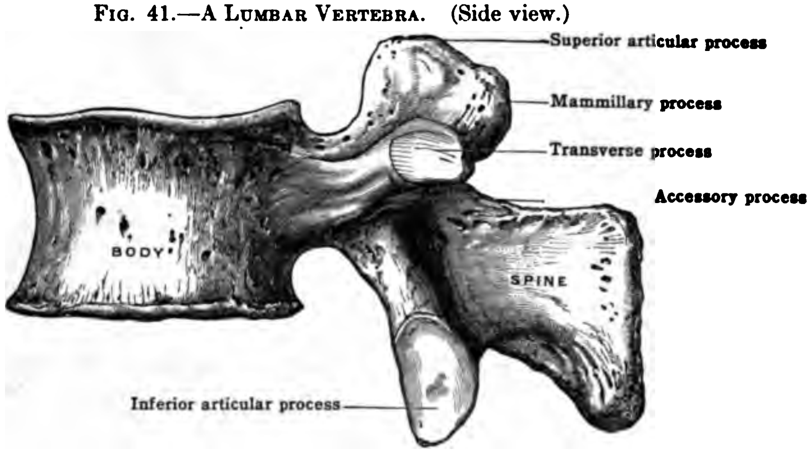
A peculiarity, more frequent in the thoracic and lumbar than in the cervical and sacral regions of the column, is the existence of a half-vertebra. Such specimens have a wedge-shaped half-centrum, to which are attached a lamina, a transverse, superior, and inferior articular, and half a spinous process. As a rule, a half-vertebra is ankylosed to the vertebræ above and below.

THE LUMBAR VERTEBRÆ

The **lumbar vertebræ** (figs. 41, 42) are distinguished by their large size and by the absence of costal articular surfaces.

The **body** is somewhat reniform, with the greatest diameter transverse, flat above and below, and generally slightly deeper in front than behind. The **roots**

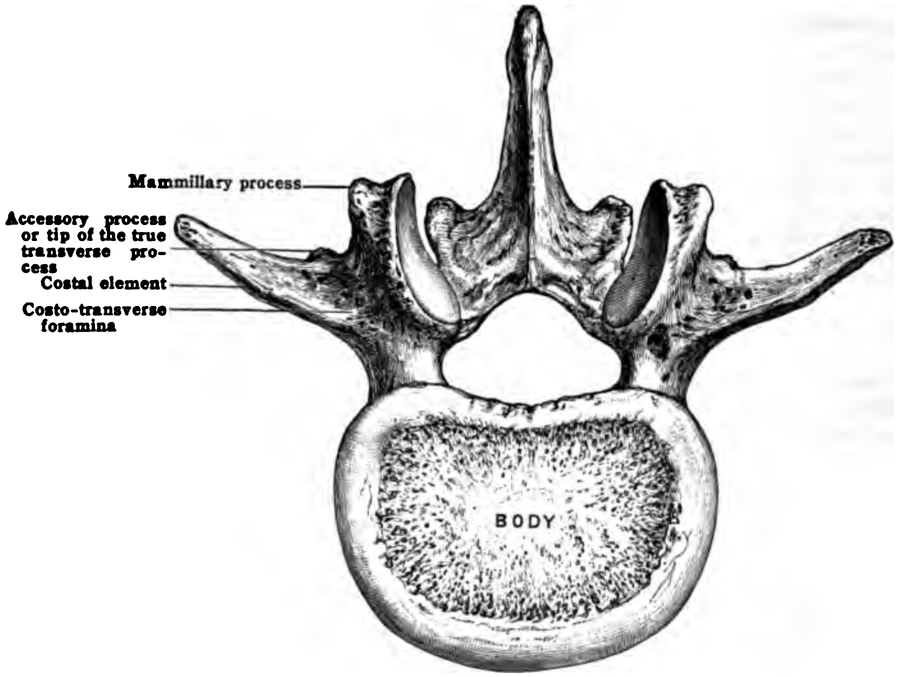
Fig. 41.—A Lumbar Vertebra. (Side view.)



(pedicles) are strong and directed straight backward, and the lower vertebral notches are deep and large. The **laminæ** are shorter and thicker than those of the thoracic or cervical vertebræ, and the **vertebral foramen** is triangular, wider than in the thoracic, but smaller than in the cervical region. The **spinous process**,

thick, broad, and somewhat quadrilateral, projects horizontally backward. It is thicker below than above and terminates in a rough posterior edge. The **articular processes** are thick and strong. The superior articular surface is concave and directed backward and medially; the inferior is convex and looks forward and laterally. The superior pair are more widely separated than the inferior pair and embrace the inferior articular processes of the vertebra above. The posterior margin of each superior articular process is surmounted by the **mammillary process** or tubercle (metapophysis) which corresponds to the superior tubercle of the transverse process of the last thoracic vertebra. In man the mammillary tubercles are rudimentary, but in some animals they attain large proportions, as in the kangaroo and armadillo. The **transverse processes** are long, slender, somewhat spatula-shaped, compressed from before backward, and directed laterally and a little backward. They are longest in the third vertebra and diminish in the fourth, second, and fifth, in this order, to the first, in which they are shortest of all. Their extremities are in series with the lateral tubercles of the transverse processes of the twelfth thoracic vertebra and also with the ribs. With the latter the so-called transverse processes in the lumbar region are homologous, and hence they are sometimes called the **costal processes.** Occasionally the costal element differentiates and becomes a well-developed lumbar rib.

FIG. 42.—A LUMBAR VERTEBRA.
(Showing the compound nature of the transverse process. Upper view.)



Behind the base of each transverse or costal process is a small eminence, directed downward, which corresponds with the inferior tubercle of the lower thoracic transverse process, and with the transverse processes of the thoracic vertebræ above, and is named the **accessory process** (anapophysis). The accessory process represents the tip of the partially suppressed true transverse process of a lumbar vertebra. It is well developed in some of the lower animals, as in the dog and cat.

Each of the five lumbar vertebræ is readily recognized. The body of the first is deeper behind than in front; the body of the second is equal in depth in front and behind; the bodies of the third, fourth, and fifth are deeper in front than behind, but the third has long transverse processes and the inferior articular processes are not widely separated. The fourth has shorter transverse processes and the inferior articular processes are placed more widely apart. The fifth lumbar vertebra deviates in some of its features so widely from the other members of the series that special prominence must now be given them.

The **fifth lumbar vertebra** is massive, and the **body** is much thicker in front

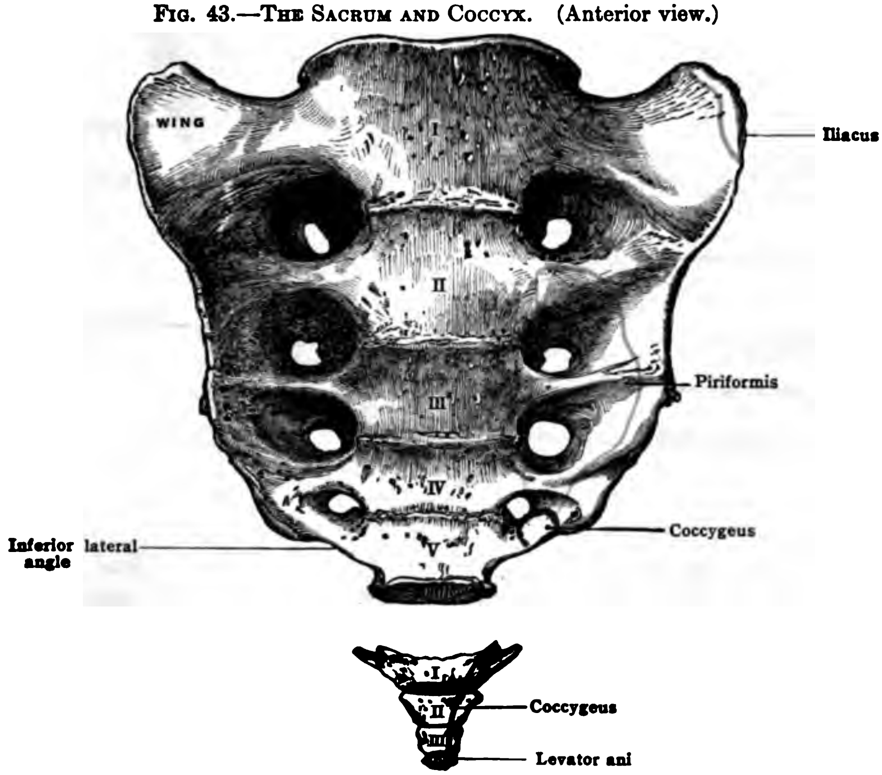
than behind in consequence of being bevelled off to form with the sacrum the *sacro-vertebral angle.* The **transverse processes** are short, thick, conical, and spring from the body as well as from the roots of the arch. They are very strong for the attachment of the ilio-lumbar ligaments. The **spinous process** is smaller than that of any of the other lumbar vertebræ; the **laminæ** project into the vertebral foramen on each side; and the **roots** are stout and flattened from above downward. The **inferior articular processes** are separated to such a degree as to be wider apart than the superior, and they articulate with the first sacral vertebra.

The roots of the arch in this vertebra are liable to a remarkable deviation from the conditions found in other parts of the spine. The peculiarity consists of a complete solution in the continuity of the arch immediately behind the superior articular processes. In such specimens the anterior part consists of the body carrying the roots, transverse and superior articular processes; whilst the posterior segment is composed of the laminæ, spine, and inferior articular processes. The posterior segment of the ring of this vertebra may even consist of two pieces. There is reason to believe that this abnormality of the fifth lumbar vertebra occurs in five per cent. of all subjects examined. Sir William Turner, in his report on the human skeletons in the Challenger Reports, found seven examples among thirty skeletons examined. The skeletons in which this occurred were:—a Malay, an Andamanese, a Chinese, two Bushmen, an Eskimo, and a Negro. Turner has also seen it in the skeleton of a Sandwich Islander. A similar condition is occasionally met with either unilaterally or bilaterally in the thoracic vertebræ.

THE SACRUM

The five sacral vertebræ (figs. 43, 44) are united in the adult to form the **os sacrum,** a large, curved, triangular bone, firmly wedged between the innominate bones, and completing, together with the coccyx, the posterior boundary of the

Fig. 43.—The Sacrum and Coccyx. (Anterior view.)



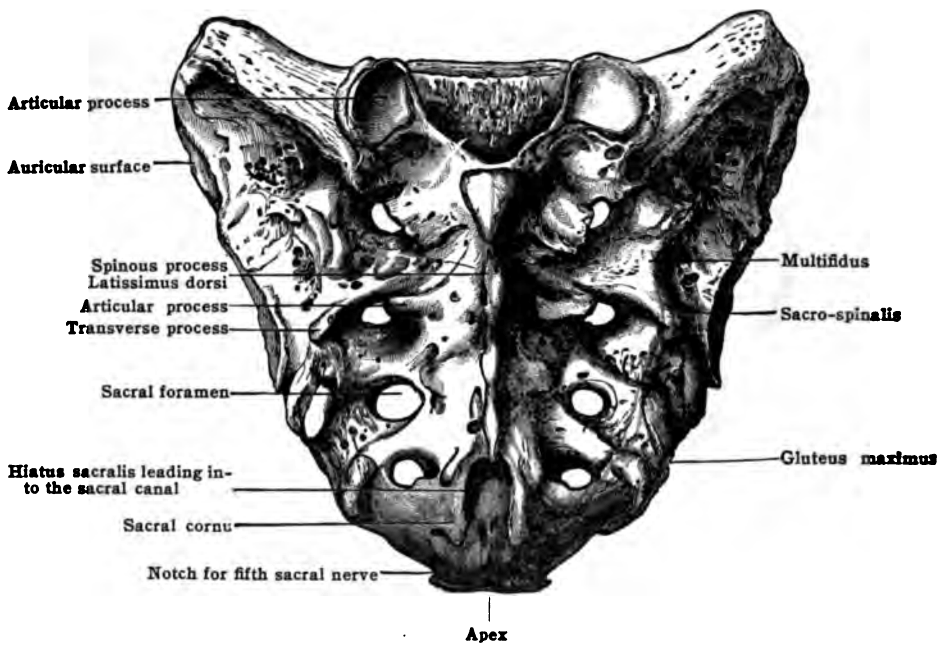
minor (or small) pelvis. Of the five vertebræ which compose the sacrum the uppermost is the largest, the succeeding ones become rapidly smaller, and the fifth is quite rudimentary. In the erect posture the sacrum lies obliquely, being directed from above downward and backward, and forms with the last lumbar vertebra an anterior projection known as the **promontory.** The sacrum presents for examination a pelvic and a dorsal surface, two lateral margins, a base, and an apex.

Surfaces.—The **pelvic surface,** directed downward and forward, is smooth, concave from above downward and slightly from side to side. It is crossed in the

middle by four transverse ridges [lineæ transversæ] which represent the ossified intervertebral discs and separate the bodies of the five sacral vertebræ. Of the bodies, the first and second are nearly equal in size and are larger than the third, fourth, and fifth, which, in vertical depth, are also nearly equal to each other. At the extremities of the transverse ridges on each side are four openings, called the **anterior sacral foramina,** which correspond to the intervertebral foramina in other regions of the column, and transmit the anterior divisions of the first four sacral nerves; they are also traversed by branches of the lateral sacral arteries. The foramina are separated by wide processes, representing the costal processes of the vertebræ, which unite laterally to form the **lateral portion** (or mass) [pars lateralis]. The latter is grooved for the sacral nerves, and rough opposite the second, third, and fourth sacral vertebræ, for the origin of the *piriformis* muscle. The lateral part of the fifth sacral vertebra gives insertion to fibres of the *coccygeus.*

The **dorsal surface** is strongly convex and rough. The middle line is occupied by four eminences representing the somewhat suppressed **spinous processes.** Of these the first is the largest, the second and third may be confluent, and the fourth is often absent. The processes are united to form an irregular ridge or

Fig. 44.—The Sacrum. (Posterior view.)



crest [crista sacralis media]. The bone on each side of the spines is slightly hollowed and is formed by the united **laminæ.** In the fourth sometimes, but always in the fifth, the laminæ fail to meet in the middle line, leaving **a gap** [**hiatus sacralis**] at the termination of the spinal canal, the lateral margins of which are prolonged downward as the **sacral cornua.** They represent the lower articular processes of the fifth sacral vertebra and give attachment to the posterior sacrococcygeal ligaments. Lateral to the laminæ is a second series of small eminences which represent the **articular** and **mammillary processes** of the vertebræ above. The first pair are large for the last lumbar vertebra, the second and third are small, and the fourth and fifth are inconspicuous. Together they form a pair of irregular ridges [cristæ sacrales articulares].

Immediately lateral to the articular processes are the **posterior sacral foramina,** four on each side; they are smaller than the anterior, and give exit to the posterior primary divisions of the first four sacral nerves. Lateral to the foramina on each side are five elevations representing the **transverse processes.** The first pair, situated at the junction of the posterior surface with the base, are large and conspicuous, and serve all for the attachment of ligaments and muscles.

Together they form on each side of the sacrum an irregular ridge [crista sacralis lateralis]. The space between the spinous and transverse processes presents a shallow concavity known as the **sacral groove**, continuous above with the vertebral groove of the movable part of the column, and, like it, lodging the *multifidus* muscle. Bridging across the groove and attached to the sacral spines medially, and to the lower and back part of the sacrum laterally, is the flat tendon of origin of the *sacro-spinalis* (*erector spinæ*). The *gluteus maximus* takes origin from the back of the lower two pieces of the sacrum.

The **base** or upper surface of the sacrum bears considerable resemblance to the upper surface of the fifth lumbar vertebra. It presents in the middle the body, of a reniform shape, posterior to which is the upper end of the sacral canal bounded by two laminæ. On each side of the canal are two articular processes bearing well-marked mammillary tubercles. The conjoined transverse and costal processes form on each side a broad surface, the wing or **ala** of the sacrum, continuous with the iliac fossa of the hip bone, and giving attachment to a few fibres of the *iliacus*.

FIG. 45.—LEFT LATERAL VIEW OF SACRUM AND COCCYX.

The lateral margins.—It has already been noted that the lateral portion of the sacrum is the part lateral to the foramina. It is broad and thick above, where it forms the ala, but narrowed below. The lateral aspect of the upper part presents in front a broad irregular surface, covered in the recent state with fibro-cartilage, which articulates with the ilium and is known as the **auricular surface.** It is bounded posteriorly by some rough depressions for the attachment of the posterior sacro-iliac ligaments. Below the auricular surface, the lateral margin is rough for the sacro-tuberous (greater) and sacro-spinous (lesser sacro-sciatic) ligaments, and terminates in the projection known as the **inferior lateral angle.** Immediately below the angle is a notch, converted into a foramen by the transverse process of the first coccygeal vertebra, and a ligament connecting this with the inferior lateral angle of the sacrum. Through this foramen passes the anterior branch of the fifth sacral nerve.

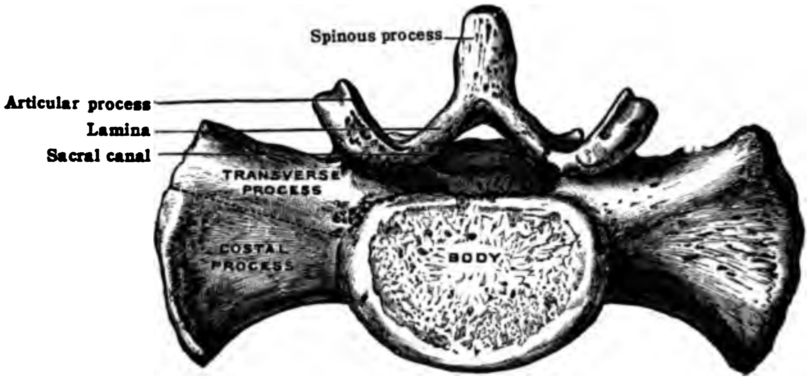
The **apex** is directed downward and forward and is formed by the inferior aspect of the body of the fifth sacral vertebra. It is transversely oval and

articulates by means of an intervertebral disc with the coccyx. In advanced life the apex of the sacrum becomes united to the coccyx by bone.

The **sacral canal** is the continuation of the spinal canal through the sacrum. Like the bone, it is curved and triangular in form at the base and flattened toward the apex. It terminates at the hiatus sacralis between the sacral cornua, where the laminæ of the fourth and fifth sacral vertebræ are incomplete. The canal opens on the surface by the anterior and posterior sacral foramina and lodges the lower branches of the cauda equina, the filum terminale, and the lower extremity of the dura and arachnoid. The sub-dural and sub-arachnoid spaces extend downward within the canal as far as the body of the third sacral vertebra.

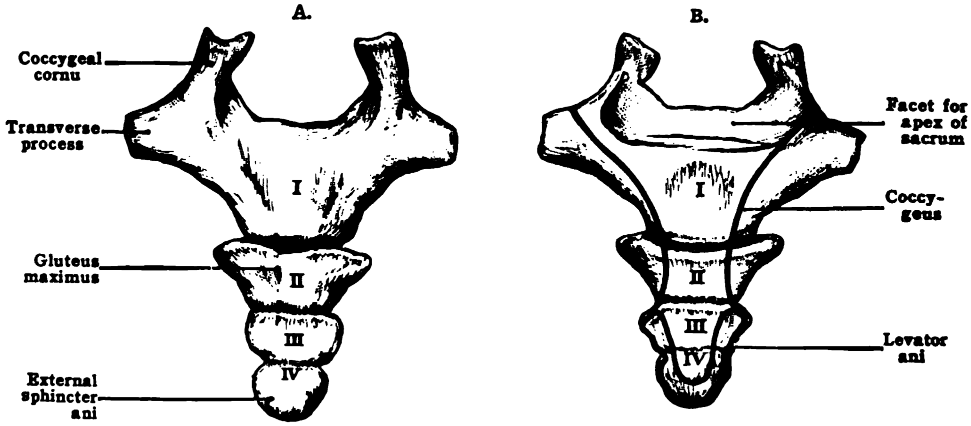
Differences in the two sexes.—The sacrum of the female is usually broader in proportion to its length, much less curved, and directed more obliquely backward than in the male. The curvature of the female sacrum belongs chiefly to the lower part of the bone, whereas in the male it is equally distributed over its whole length; but the curvature is subject to considerable variation in different skeletons.

Fig. 46.—Base of Sacrum.



Racial differences.—The human sacrum is characterised by its great breadth in comparison with its length, though in the lower races it is relatively longer than in the higher. The proportion is expressed by the *sacral index* $= \frac{\text{breadth} \times 100}{\text{length}}$. The average sacral index in the British male is 112, in the female 116. Sacra in which the index is above 100 are *platyhieric*, as in Europeans; those under 100 are *dolichohieric*, as in most of the black races (Sir W. Turner).

Fig. 47.—The Coccyx. A. Posterior view; B. Anterior view.



THE COCCYGEAL VERTEBRÆ

The four coccygeal vertebræ are united in the adult to form the **coccyx** [os coccygis] (fig. 47). While four is the usual number of these rudimentary vertebræ, occasionally there are five, and rarely three. In middle life the first piece is usually separate, and the original division of the remaining portion of the coccyx

into three parts is indicated by transverse grooves. In advanced life the pieces of the coccyx, having previously united to form one bone, may also become joined to the sacrum.

The first piece of the coccyx is much broader than the others. It consists of a body, transverse processes, and rudiments of a neural arch. The body presents on its upper surface an oval facet for articulation with the apex of the sacrum. On each side of the body a **transverse process** projects laterally and is joined either by ligament or bone to the inferior lateral angle of the sacrum, forming a foramen for the anterior division of the fifth sacral nerve. From the posterior surface of the body two long **coccygeal cornua** project upward and are connected to the sacral cornua by the posterior sacro-coccygeal ligaments, enclosing on each side an aperture —the last intervertebral foramen—for the exit of the fifth sacral nerve. The coccygeal cornua represent the roots and superior articular processes of the first coccygeal vertebra.

The **second** piece of the coccyx is much smaller than the first, and consists of a body, traces of transverse processes, and a neural arch, in the form of slight tubercles at the sides and on the posterior aspect of the body.

The **third** and **fourth** pieces of the coccyx, smaller than the second piece, are mere nodules of bone, corresponding solely to vertebral bodies.

The **anterior surface** of the coccyx gives attachment to the anterior sacro-coccygeal ligament and near the tip to the *levator ani;* it is in relation with the posterior surface of the rectum.

The **posterior surface** of the coccyx is convex, and the upper three pieces afford attachment to the *gluteus maximus* on each side, and the last piece to the coccygeal portion of the *sphincter ani externus.*

The **lateral margins** are thin, and receive parts of the sacro-sciatic ligaments, of the *coccygei* muscles, and of the *levatores ani.*

THE VERTEBRAL COLUMN AS A WHOLE

The vertebral column (fig. 48) is the central axis of the skeleton and is situated in the median line at the posterior aspect of the trunk. Superiorly it supports the skull; laterally it gives attachment to the ribs, through which it receives the weight of the upper limbs, and inferiorly it is supported by the hip bones, by which the weight of the trunk is transmitted to the lower limbs. Its length varies in different skeletons, but on an average it measures about 70 cm. (28 in.) in the male and about 2.5 cm. (1 in.) less in the female. To the entire length the cervical region contributes 12.5 cm. (5 in.), the thoracic 27.5 cm. (11 in.), the lumbar 17.5 cm. (7 in.), and the sacro-coccygeal portion the remaining 12.5 cm. (5 in.). The vertebral column presents a series of curvatures, four when viewed in profile and one when viewed from the front or back. The former are directed alternately forward and backward, and are named, from the regions of the column in which they occur, **cervical, thoracic, lumbar,** and **sacral.** The fifth curve is **lateral,** being in most cases directed toward the right side.

The cervical, thoracic and lumbar curvatures pass imperceptibly into one another, but at the junction of the last lumbar vertebra with the sacrum a well-marked angle occurs, known as the **sacro-vertebral** or **lumbo-sacral** angle, with the result that the promontory of the sacrum overhangs the cavity of the minor (small)pelvis and forms a portion of the superior aperture of the small pelvis.

The thoracic and sacral curves have their concavities directed forward and are developed during intra-uterine life. They are in obvious relation to two great cavities of the trunk, thoracic and pelvic, and may be regarded as **primary** or **accommodation curves,** for the thoracic and pelvic viscera. The thoracic curve extends from the second to the twelfth thoracic vertebra and the sacral curve coincides with the sacrum and coccyx.

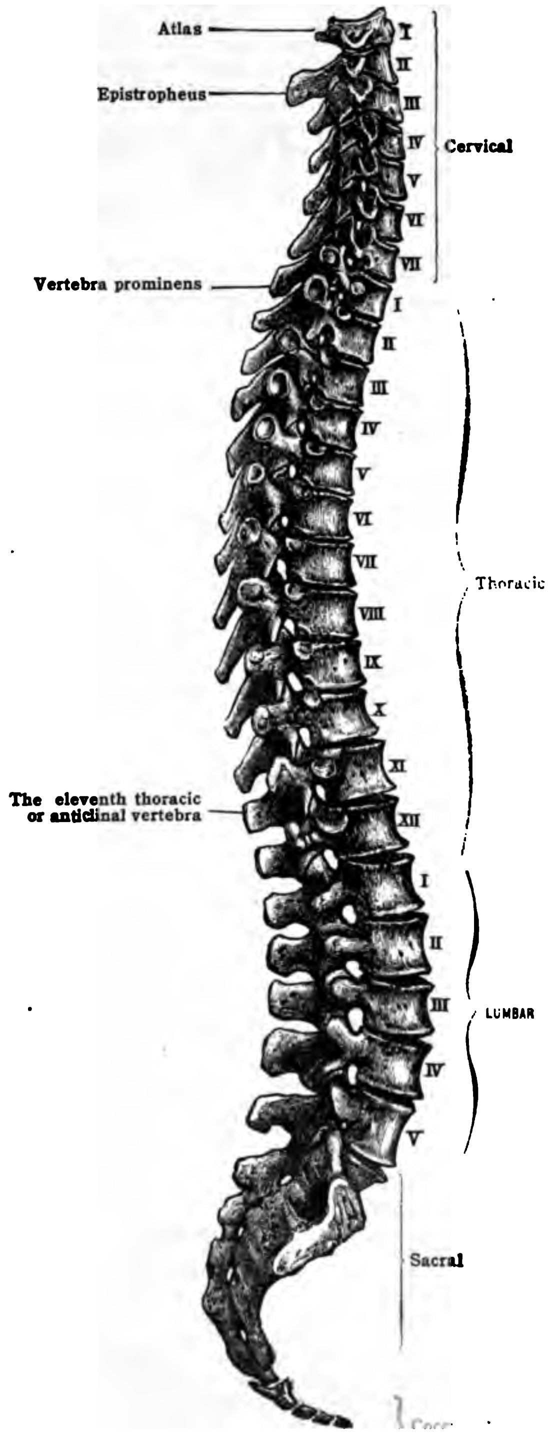
The cervical and lumbar curves have their convexities directed forward, and are developed during the first year after birth. They are essentially curves of **compensation,** necessary for the maintenance of the upright posture, and are brought about by modifications in the shape of the intervertebral discs. The cervical curve is formed about the third month, or as soon as the infant can sit upright. The great peculiarity of the curve is that it is never consolidated, being present when the body is placed in the erect position and obliterated by bending the head down upon the chest. The lumbar curve is developed about the end of the first year or when the child begins to walk, but is not consolidated until adult life. (Symington.) The cervical curve extends from the atlas to the second thoracic vertebra, and the lumbar curve from the twelfth thoracic to the promontory of the sacrum.

The lateral curve is situated in the upper thoracic region, and when directed to the right is probably associated with the greater use made of the right hand. This curve, however, is particularly liable to modification in different occupations and in different races.

Viewed from the front, the vertebral column presents a series of **pyramids** due to the successive increase and decrease in size of the bodies. These become broader from the axis to the first thoracic vertebra and then decrease to the fourth thoracic. The first pyramid therefore includes all the cervical vertebræ except the atlas, and has the apex directed upward and its base downward, whilst the second is inverted and formed by the first four thoracic vertebræ. The third pyramid, much the longest, is the result of the increase in size from the fourth thoracic to the fifth lumbar vertebra, and the fourth, which is inverted, is produced by the rapid contraction of the sacral and coccygeal vertebræ.

Viewed from behind, the spinous processes project in the middle line, and the transverse processes as two lateral rows. Of the spines, those of the axis, seventh cervical, first thoracic, and the lumbar vertebræ appear most prominent. On each side is the **vertebral groove,** the floor of which is formed in the cervical and lumbar regions by the laminæ and articular processes,

FIG. 48.—VERTEBRAL COLUMN. (Lateral view.)

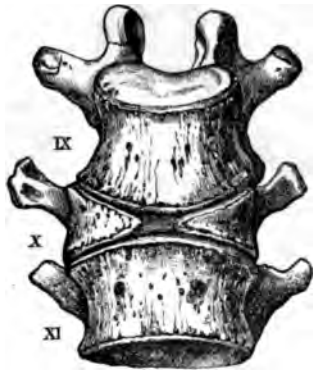


and in the thoracic region, by the laminæ and transverse processes. The transverse processes project laterally for a considerable distance in the atlas, first thoracic, and the middle of the lumbar series; they are shortest in the third cervical and the twelfth thoracic.

In the lateral view, the intervertebral foramina appear oval in shape, and are small in the cervical, larger in the thoracic, and largest in the lumbar region.

Structure of a vertebra.—The bodies of the vertebræ are largely composed of cancellous tissue, with a thin outer covering of compact tissue. In a vertical section through the centrum

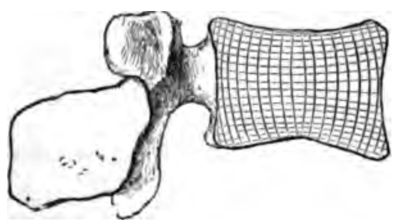
FIG. 49.—A DIVIDED THORACIC VERTEBRA. (After Turner.)



the fibres of the cancellous tissue are seen to be arranged vertically and horizontally, the vertical fibres being curved with their concavities directed toward the centre of the bone. The horizontal fibres are slightly curved parallel with the upper and lower surfaces, and have their convexities toward the centre of the bone. They are not so well defined as the vertical set. (Wagstaffe.)

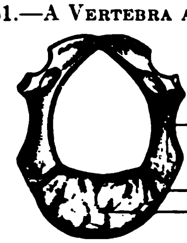
Ossification.—The vertebræ in general.—The ossification of each vertebra takes place in cartilage from three primary and five secondary centres. The three primary centres

FIG. 50.—A VERTEBRAL CENTRUM IN SECTION TO SHOW THE PRESSURE CURVES.



appear, one in the body and two in the arch, about the seventh week of intra-uterine life. In the thoracic region the nucleus for the body appears first, but in the cervical region it is preceded by the centres for the arch. The nucleus for the body soon becomes bilobed, and this condition is sometimes so pronounced as to give rise to the appearance of two distinct nuclei. Indeed, the nucleus is very rarely double and the two parts of the body may remain separate throughout life (fig. 49). The bilateral character of the nucleus is further emphasised by the occasional formation of half-vertebræ. The lateral centres are deposited near the bases of the

FIG. 51.—A VERTEBRA AT BIRTH.



superior articular processes and give rise to the roots, laminæ, articular, and the greater parts of the transverse and spinous processes.

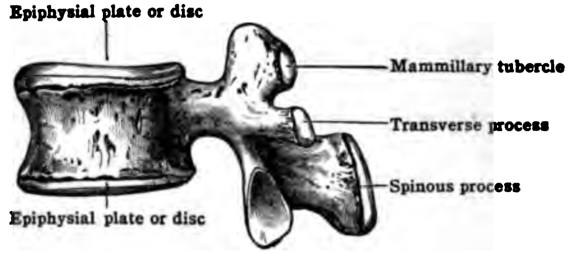
At birth a typical vertebra consists of three osseous pieces—a body and two lateral masses, which constitute the arch, the parts being joined together by hyaline cartilage. The line of union of the lateral portion with the body is known as the *neuro-central suture*, and is not actually obliterated for several years after birth. In the thoracic region the central ossification does not pass beyond the point with which the head of the rib articulates, and leaves a portion of the body on each side formed from the lateral ossification. A thoracic vertebra at the fifth year shows

that the pits for the heads of the ribs are situated behind the neuro-central suture, which is directed obliquely backward and medially. The laminæ unite during the first year after birth; and by the gradual extension of ossification into the various processes, the vertebræ have attained almost their full size by the time of puberty. Subsequently the secondary centres appear in the cartilaginous extremities of the spinous and transverse processes, and in the carti-

FIG. 52.—CERVICAL VERTEBRA SHOWING THE EPIPHYSIAL PLATE ON THE UPPER SURFACE OF THE BODY.

lage on the upper and lower surfaces of the bodies, forming in each vertebra two annular plates, thickest at the circumference and gradually thinning toward the central deficiency. The epiphyses appear from the fifteenth to the twentieth year and join with the vertebra by the twenty-fifth year.

FIG. 53.—LUMBAR VERTEBRA AT THE EIGHTEENTH YEAR WITH SECONDARY CENTRES.

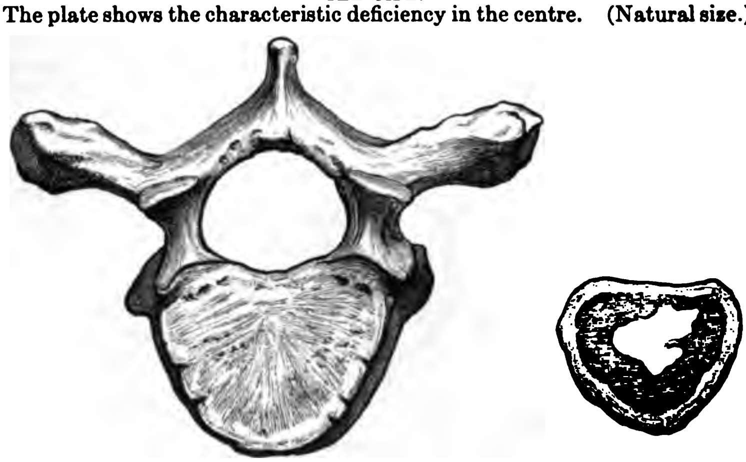


In several vertebræ the mode of ossification differs from the account given above—in some cases considerably—and necessitates separate consideration.

Atlas.—The lateral portions and posterior arch are formed from two centres of ossification, which correspond to the lateral centres of other vertebræ and appear about the seventh week.

FIG. 54.—UPPER THORACIC VERTEBRA WITH AN EPIPHYSIAL PLATE REMOVED AND DRAWN AT THE SIDE.

The plate shows the characteristic deficiency in the centre. (Natural size.)



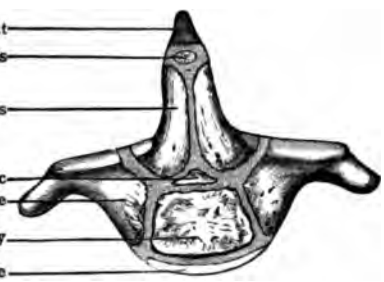
The anterior arch is ossified from one centre, which, however, does not appear until a few months after birth. Union of the lateral parts occurs posteriorly in the third year, being sometimes preceded by the appearance of a secondary centre of ossification in the intervening cartilage, and the union of the lateral parts with the anterior arch occurs about the sixth year.

Epistropheus.—The arch, and the processes associated with it, are formed from two lateral centres which appear, like those in the other vertebræ, about the seventh week. The common piece of cartilage which precedes the body and dens is ossified from four (or five) centres, one (or two) for the body of the axis, in the fourth month, two, laterally disposed, for the dens, a

Fig. 55.—Immature Atlas. (Third year.)

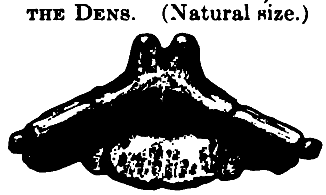
few weeks later, and one, for the apex of the dens, in the second year. The two collateral centres for the main part of the dens soon coalesce, so that at birth the axis consists of four osseous pieces —two lateral portions which constitute the arch, the body, and the dens, surmounted by a piece of cartilage. During the third or fourth year the dens joins with the body, the line of

Fig. 56.—Development of the Epistropheus.



union being indicated even in advanced life by a small disc of cartilage, and the arch unites in front and behind about the same time or a little later. The apical nucleus of the dens, which represents an epiphysis, joins the main part about the twelfth year and in the seventeenth year

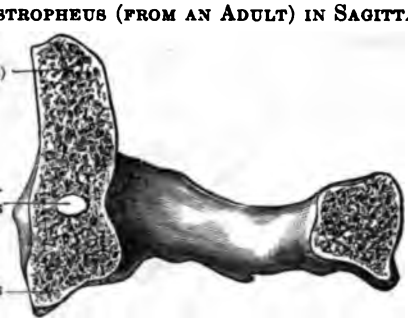
Fig. 57.—The Epistropheus at Four Years of Age, showing the Size and Extent of the Dens. (Natural size.)



an epiphysial plate appears for the lower surface of the body. There are also rudiments, adjoining the cartilaginous disc, of the upper epiphysial plate of the body.

Cervical vertebræ.—In the cervical vertebræ the lateral centres form a larger share of the body than in the vertebræ of other regions, and the neuro-central suture runs almost in a sag-

Fig. 58.—The Epistropheus (from an Adult) in Sagittal Section.

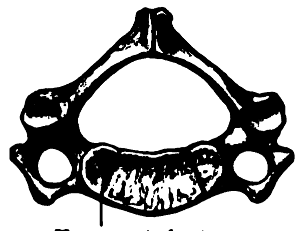


ittal direction. The sixth, seventh, and even the fifth have additional centres which appear before birth for the anterior or costal divisions of the transverse processes. In the other cervical vertebræ the costal processes are ossified by extension of the lateral nuclei. The costal processes of the seventh cervical sometimes remain separate, constituting cervical ribs.

Lumbar vertebræ.—In the lumbar vertebræ the neuro-central suture is almost transverse, and to the usual number of centres of ossification, two other epiphyses for the mammillary tubercles are added, the centres appearing about puberty. The transverse process of the first lumbar vertebra is occasionally developed from an independent centre.

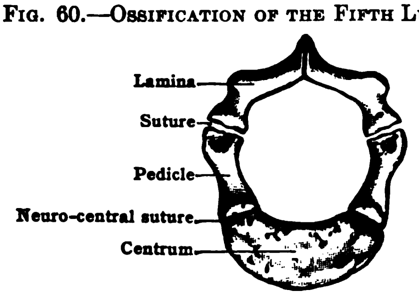
The fifth lumbar exhibits in some cases a special mode of ossification in the arch. Instead of two centres, there are four—one on each side for the root, transverse process, and superior articular process, and another on each side for the lamina, inferior articular process, and the lateral half of the spinous process (fig. 60). There may be failure of union of roots with the laminæ or of the laminæ with one another.

Fig. 59.—An Immature Cervical Vertebra.



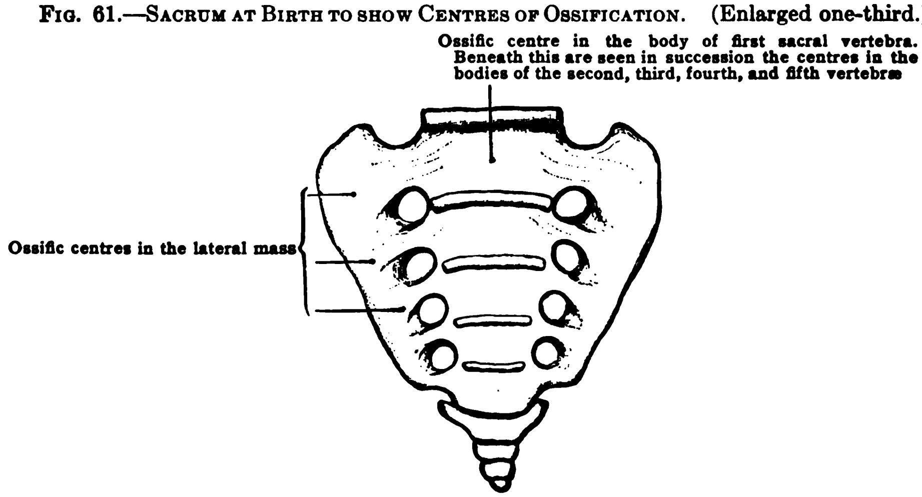
Sacral vertebræ.—The sacrum ossifies from thirty-five centres, which may be classified as follows:—In each of the five vertebræ there are three primary nuclei—one for the body and two for the arch; in each of the first three the costal element of the lateral mass on each side is formed from a separate nucleus; associated with each body are two epiphysial plates; and on each lateral margin are two irregular epiphyses, one for the auricular surface and another for the rough edge below.

Fig. 60.—Ossification of the Fifth Lumbar Vertebra.



The centres for the bodies appear about the eighth or ninth week and for the vertebral arches about the sixth month. The arches join the bodies at different times in the different vertebræ, ranging from the second year below, to the fifth or sixth year above, and union of the laminæ takes place behind some years later, from about the ninth to the fifteenth year.

Fig. 61.—Sacrum at Birth to show Centres of Ossification. (Enlarged one-third.)

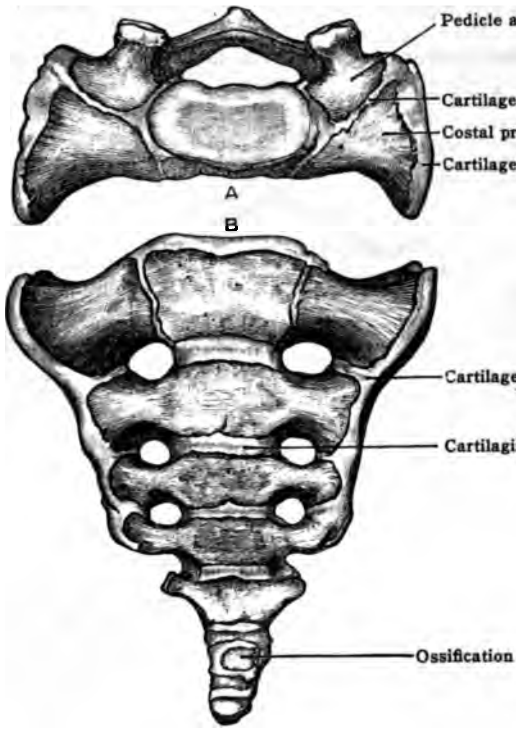


The centres for the costal elements appear outside the anterior sacral foramina, from the fifth to the seventh month, and these unite with the bodies somewhat later than the arches.

The centres for the epiphysial plates appear about the fifteenth year, and for the auricular epiphyses and the edges below, from the eighteenth to the twentieth year.

Consolidation begins soon after puberty by fusion of the costal processes, and this is followed by ossification from below upward in the intervertebral discs, resulting in the union of the adjacent bodies and the epiphysial plates, the ossific union of the first and second being completed by the twenty-fifth year or a little later. The marginal epiphyses are also united to the

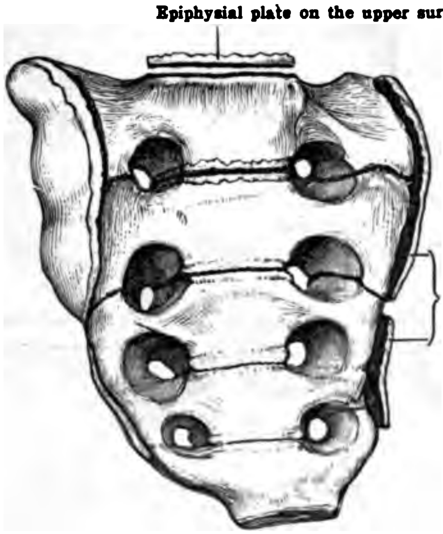
FIG. 62.—THE SACRUM AT FOUR YEARS OF AGE (B). THE FIGURE AT THE TOP (A) SHOWS THE BASE DRAWN FROM ABOVE. (Three-fourths natural size.)



sacrum by the twenty-fifth year. Even in advanced life intervertebral discs persist in the more central parts of the bone and can be well seen in sections.

Coccygeal vertebræ.—The coccygeal vertebræ are cartilaginous at birth and each is usually ossified from a single centre, though there may be two for the first piece. Ossification begins soon after birth in the first segment, and in the second from the fifth to the tenth year.

FIG. 63.—SACRUM AT ABOUT TWENTY-TWO YEARS. (Three-fifths natural size.)



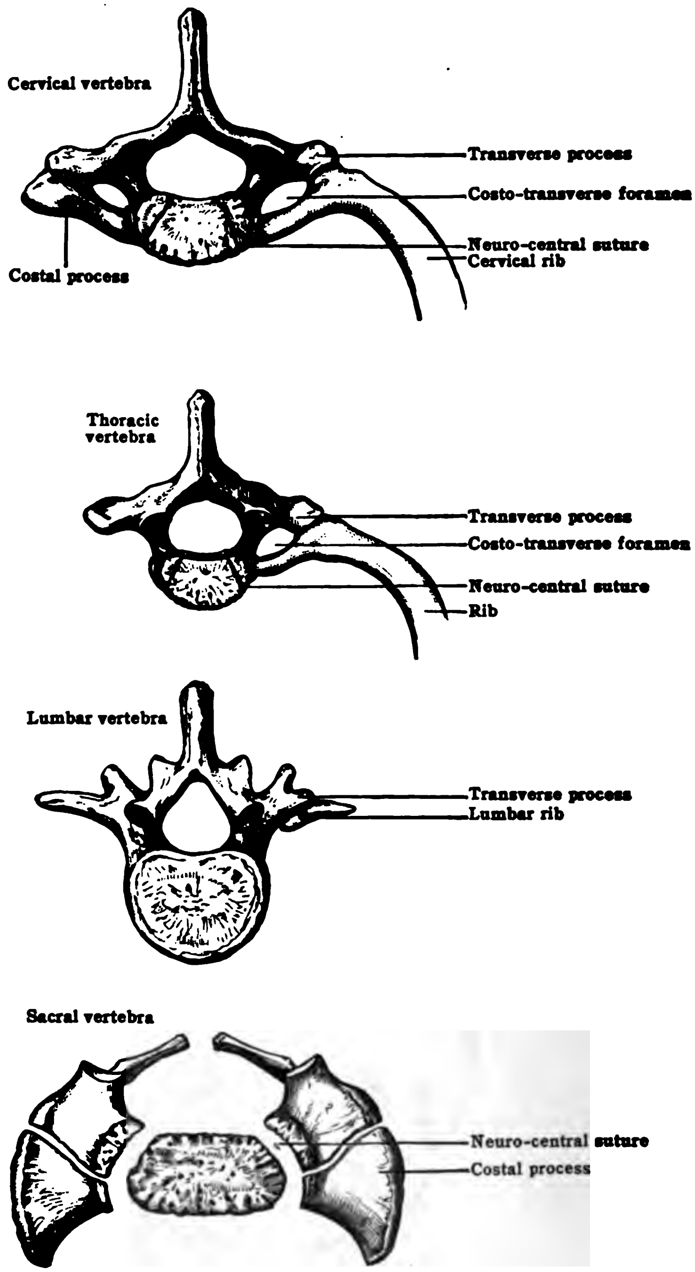
The centres for the third and fourth segments appear just before, and after, puberty respectively. As age advances the various pieces become united with each other, the three lower uniting before middle life and the upper somewhat later. In advanced life the coccyx may join with the sacrum, the union occurring earlier and more frequently in the male than in the female.

The Serial Morphology of the Vertebræ

Although at first sight many of the vertebræ exhibit peculiarities, nevertheless a study of the mode by which they develop, and their variations, indicates the serial homology of the constituent parts of the vertebræ in each region of the column.

The body (centrum) of the vertebra is that part which immediately surrounds the notochord. This part is present in all the vertebræ of man, but the centrum of the atlas is dissociated from its arch, and ankylosed to the body of the epistropheus. The reasons for regard-

Fig. 64.—Morphology of the Transverse and Articular Processes.



ing the dens as the body of the atlas are these: In the embryo the notochord passes through it on its way to the base of the cranium. Between the dens and the body of the axis there is a swelling of the notochord in the early embryo as in other intervertebral regions. This swelling is later indicated by a small intervertebral disc hidden in the bone, but persistent even in old age. Moreover, the dens ossifies from primary centres, and in chelonians it remains as a separate ossicle throughout life; in Ornithorhynchus it remains distinct for a long time, and it has been found separate even in an adult man. Lastly, in man and many mammals, an epi-

physial plate develops between it and the body of the axis. The anterior arch of the atlas represents a cartilaginous *hypochordal bar*, which is present in the early stages of development of the vertebræ, but disappears in all but the atlas in the ossification of the body.

The *arches* and *spinous processes* are easily recognised throughout the various parts of the column in which complete vertebræ are present.

The *articular processes* or *zygapophyses* are of no morphological value, and do not require consideration here.

The *transverse processes* offer more difficulty. They occur in the simplest form in the thoracic series. Here they articulate with the tubercles of the ribs, whence the term *tubercular processes* or *diapophyses* has been given them (the place of articulation of the head of the rib with the vertebra is the *capitular process* or *parapophysis*), and the transverse process and the neck of the rib enclose an arterial foramen named the costo-transverse foramen. In the cervical region the costal element (*pleurapophysis*) and the transverse process are fused together, and the conjoint process thus formed is pierced by the costo-transverse foramen. The compound nature of the process is indicated by the fact that the anterior or costal processes in the lower cervical vertebræ arise from additional centres and occasionally retain their independence as cervical ribs, and in Sauropsida (birds and reptiles) these processes are represented by free ribs. In the lumbar region, the compound nature of the transverse process is further marked. The true transverse process is greatly suppressed, and its extremity is indicated by the accessory tubercle. Anterior to this in the adult vertebræ a group of holes represents the costo-transverse foramen, and the portion in front of this is the costal element. Occasionally it persists as an independent ossicle, the lumbar rib.

In the sacral series the costal elements are coalesced in the first three vertebræ to form the greater portion of the lateral portion for articulation with the ilium, the costo-transverse foramina being completely obscured. In rare instances the first sacral vertebra will articulate with the ilium on one side, but remain free on the other, and under such conditions the free process exactly resembles the elongated transverse process of a lumbar vertebra. The first three sacral vertebræ which develop costal processes for articulation with the ilium are termed *true sacral* vertebræ, while the fourth and fifth are termed *pseudo-sacral*. A glance at fig. 64 will show the homology of the various parts of a vertebra from the cervical, thoracic, lumbar, and sacral regions.

B. BONES OF THE SKULL

The skull is the expanded upper portion of the axial skeleton and is supported on the summit of the vertebral column. It consists of the **cranium,** a strong bony case enclosing the brain and made up of eight bones—viz., *occipital*, two *parietal*, *frontal*, two *temporal*, *sphenoid*, *ethmoid;* and the **bones of the face,** surrounding the mouth and nose, and forming with the cranium the orbital cavity for the reception of the eye. The bones of the face are fourteen in number—viz., two *maxillæ*, two *zygomatic* (*malar*), two *nasal*, two *lacrimal*, two *palate*, two *inferior conchæ* (*turbinates*), the *mandible*, and the *vomer*. All the bones enumerated above, with the exception of the mandible, are united by suture and are therefore immovable. The proportion between the facial and cranial parts of the skull varies at different periods of life, being in the adult about one (facial) to two (cranial), and in the new-born infant about one to eight. A group of movable bones, comprising the *hyoid*, suspended from the basilar surface of the cranium, and three small bones, the *incus*, *malleus*, and *stapes*, situated in the middle ear or tympanic cavity, is also included in the enumeration of the bones of the skull.

According to the BNA nomenclature, the term *cranium* is used in a wider sense as synonymous with *skull*, and is subdivided into *cranium cerebrale* (cranium in the narrower sense) and *cranium viscerale* (facial skeleton). In the BNA, seven bones above listed with the facial,—two inferior conchæ, two lacrimal, two nasal and the vomer—are classed with the cranium cerebrale.

THE OCCIPITAL

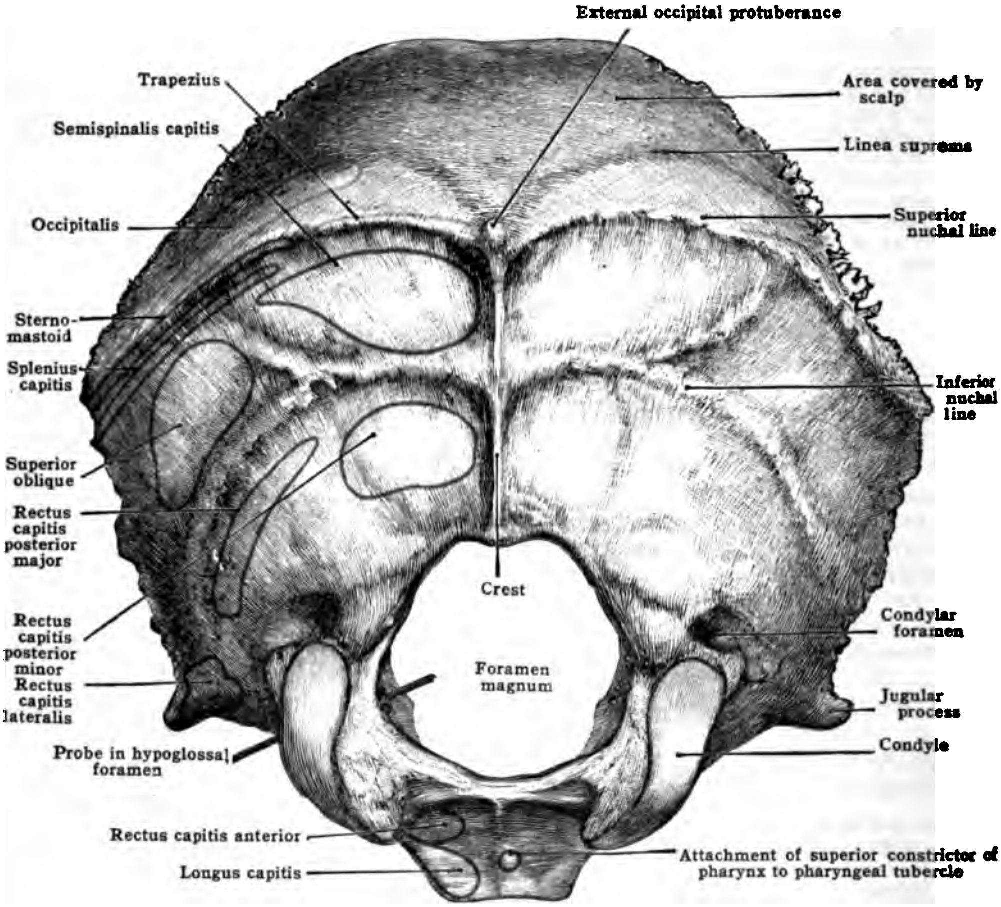
The **occipital bone** [os occipitale] (fig. 65) is situated at the posterior and inferior part of the cranium. In general form it is flattened and trapezoid in shape, curved upon itself so that one surface is convex and directed backward and somewhat downward, while the other is concave and looks in the opposite direction. It is pierced in its lower and front part by a large aperture, the **foramen magnum,** by which the vertebral canal communicates with the cavity of the cranium.

The occipital bone is divisible into four parts, **basilar, squamous,** and two **condylar,** so arranged around the foramen magnum that the basilar part lies in front, the condylar parts on either side, and the squamous part above and behind.

Speaking generally, this division corresponds to the four separate parts of which the bone consists at the time of birth (fig. 69), known as the **basi-occipital, supra-occipital, and ex-occipital.** In early life these parts fuse together, the lines of junction of the supra-occipital and ex-occipitals extending lateralward from the posterior margin of the foramen magnum, and those of the ex-occipitals and basi-occipital passing through the condyles near their anterior extremities. It must be noted, however, that the upper portion of the squamous part represents an additional bone, the **interparietal.**

The **squamous part** [squama occipitalis] (supra-occipital and interparietal) presents on its convex **posterior surface,** and midway between the superior angle and the posterior margin of the foramen magnum, a prominent tubercle known as the **external occipital protuberance,** from which a vertical ridge—the **external occipital crest**—runs downward and forward as far as the foramen. The protuberance and crest give attachment to the ligamentum nuchæ.

FIG. 65.—THE OCCIPITAL. (External view.)



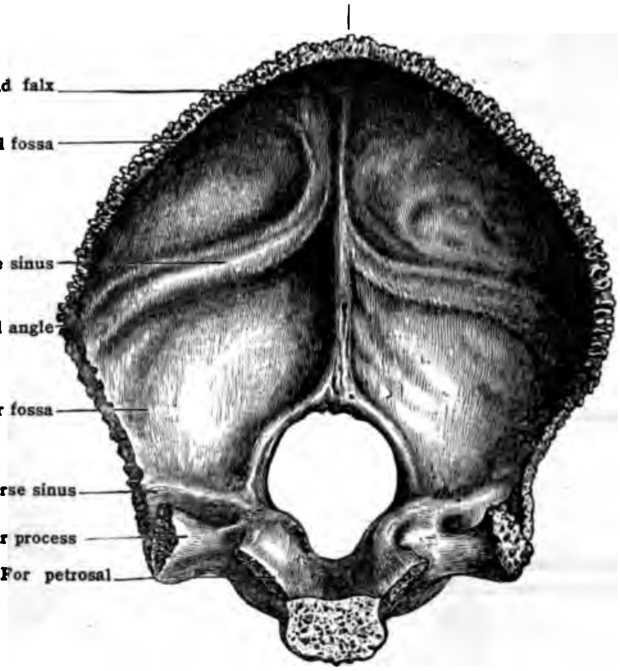
Arching lateralward on each side from the external occipital protuberance toward the lateral angle of the bone is a semicircular ridge, the **superior nuchal line** [linea nuchæ superior], which divides the surface into two parts—an upper [planum occipitale] and a lower [planum nuchale]. Above this line, a second less distinctly marked ridge—the **highest nuchal line** [linea nuchæ suprema]—is usually seen. It is the most curved of the three lines on this surface and gives attachment to the epicranial aproneuosis and to a few fibres of the *occipitalis* muscle. Between the superior and highest curved lines is a narrow crescentic area in which the bone is smoother and denser than the rest of the surface, whilst the part of the bone above the linea suprema is convex and covered by the scalp.

The lower part of the surface is very uneven and subdivided into an upper and a lower area by the **inferior nuchal line,** which runs laterally from the middle of the crest to the jugular process.

The curved lines and the areas thus mapped out between and below them give attachment to several muscles. To the superior nuchal line are attached, medially the *trapezius*, and laterally the *occipitalis* and *sterno-cleido-mastoid;* the area between the superior and inferior curved lines receives the *semispinalis capitis* (*complexus*) medially, and *splenius capitis* and *obliquus capitis superior* laterally; the inferior nuchal line and the area below it afford insertion to the *rectus capitis posterior minor* and *major*.

The **anterior** or **cerebral surface** is deeply concave and marked by two grooved ridges which cross one another and divide the surface into four fossæ of which the two upper, triangular in form, lodge the occipital lobes of the cerebrum, and the two lower, more quadrilateral in outline, the lobes of the cerebellum. The vertical ridge extends from the superior angle to the foramen magnum and the transverse ridge from one lateral angle to the other, the point of intersection being indicated by the **internal occipital protuberance** [eminentia cruciata]. The

FIG. 66.—OCCIPITAL BONE, CEREBRAL SURFACE.



upper part of the vertical ridge is grooved [sulcus sagittalis] for the superior sagittal (*longitudinal*) sinus and gives attachment, by its margins, to the falx cerebri; the lower part is sharp and known as the **internal occipital crest,** and affords attachment to the falx cerebelli. Approaching the foramen magnum the ridge divides, and the two parts become lost upon its margin. The angle of divergence sometimes presents a shallow fossa for the extremity of the vermis of the cerebellum, and is called the **vermiform fossa.** The two parts of the transverse ridge are deeply grooved [sulcus transversus] for the transverse (*lateral*) sinuses, and the margins of the groove give attachment to the tentorium cerebelli. To one side of the internal occipital protuberance is a wide space, where the vertical groove is continued into one of the lateral grooves (more frequently the right), and this is termed the torcular Herophili; it is sometimes exactly in the middle line.

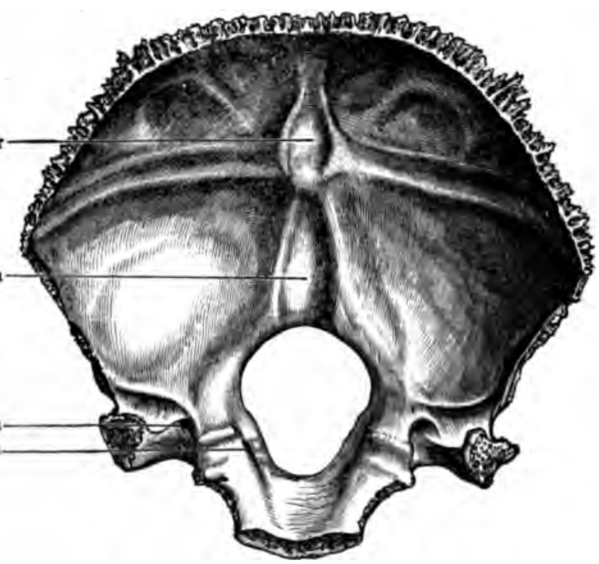
The squamous portion has three angles and four borders. The **superior angle** forming the summit of the bone is received into the space formed by the union of the two parietals. The **lateral angles** are very obtuse and correspond in situation with the lateral ends of the transverse ridges. Above the lateral angle on each side the margin is deeply serrated, forming the **lambdoid** or **superior border** which extends to the superior angle and articulates with the posterior border of the parietal in the lambdoid suture. The **mastoid** or **inferior border** extends

from the lateral angle to the jugular process and articulates with the **mastoid** portion of the temporal.

The **condylar** or **lateral portions** [partes laterales] (ex-occipitals) form the lateral boundaries of the foramen magnum and bear the condyles on their inferior surfaces. The **condyles** are two convex oval processes of bone with smooth articular surfaces, covered with cartilage in the recent state, for the superior articular processes of the atlas. They converge in front, and are somewhat everted. Their margins give attachment to the capsular ligaments of the occipito-atlantal joints and on the medial side of each is a prominent tubercle for the alar (lateral odontoid) ligament. The anterior extremities of the condyles extend beyond the ex-occipitals on the basi-occipital portion of the bone. The **hypoglossal** (anterior condyloid) **foramen** or **canal** [canalis hypoglossi] perforates the bone at the base of the condyle, and is directed from the interior of the cranium, just above the foramen magnum, forward and laterally; it transmits the hypoglossal nerve and a twig of the ascending pharyngeal artery.

The foramen is sometimes double, being divided by a delicate spicule of bone. Above the canal is a smooth convexity known as the **tuberculum jugulare** sometimes marked by an oblique groove for the ninth, tenth and eleventh cranial nerves. Posterior to each condyle is a pit, the

FIG. 67.—CEREBRAL SURFACE OF THE OCCIPITAL, SHOWING AN OCCASIONAL DISPOSITION OF THE CHANNELS.



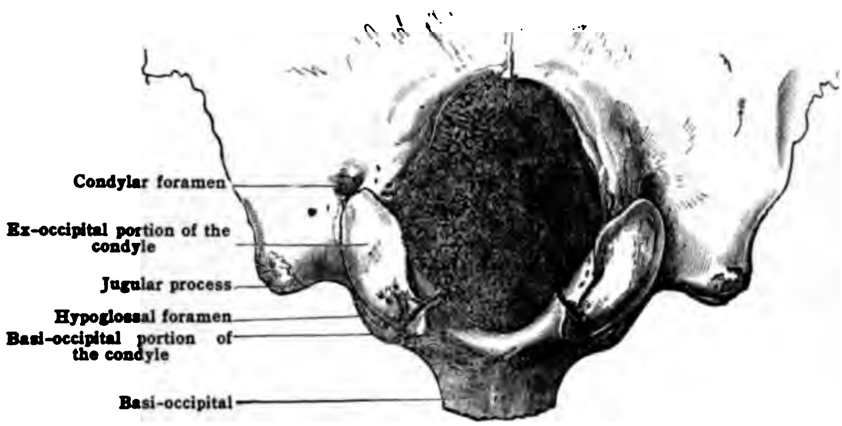
condylar fossa, which receives the hinder edge of the superior articular process of the atlas when the head is extended. The floor of the depression is occasionally perforated by the **condylar** (posterior condyloid) **canal** or **foramen** [canalis condyloideus], which transmits a vein from the **transverse** sinus. Projecting laterally opposite the condyle is a quadrilateral portion of bone known as the **jugular process,** the extremity of which is rough for articulation with the jugular facet on the petrous portion of the temporal bone. Up to twenty-five years the bones are united here by means of cartilage; about this age ossification of the cartilage takes place, and the jugular process thus becomes fused with the petrosal. Its anterior border is deeply notched to form the posterior boundary of the jugular foramen, and the notch is directly continuous with a groove on the upper surface which lodges the termination of the transverse sinus. In or near the groove is seen the inner opening of the condylar foramen. The lower surface of the process gives attachment to the *rectus capitis lateralis* and the oblique occipito-atlantal ligament. Occasionally the mastoid air cells extend into this process and rarely a process of bone, representing the *paramastoid process* of many mammals, projects downward from its under aspect and may be so long as to join or articulate with the transverse process of the atlas.

The **basilar portion** (basi-occipital) is a quadrilateral plate of bone projecting forward and upward in front of the foramen magnum. Its superior surface presents a deep groove—the **basilar groove** [clivus]; it supports the medulla oblongata and gives attachment to the tectorial membrane (occipito-axial ligament). The lower surface presents in the middle line a small elevation known as the **pharyngeal tubercle** for the attachment of the fibrous raphé of the pharynx, and immediately in front of the tubercle there is frequently a shallow

fossa—the **scaphoid fossa**—which originally received the primitive anterior extremity of the foregut.

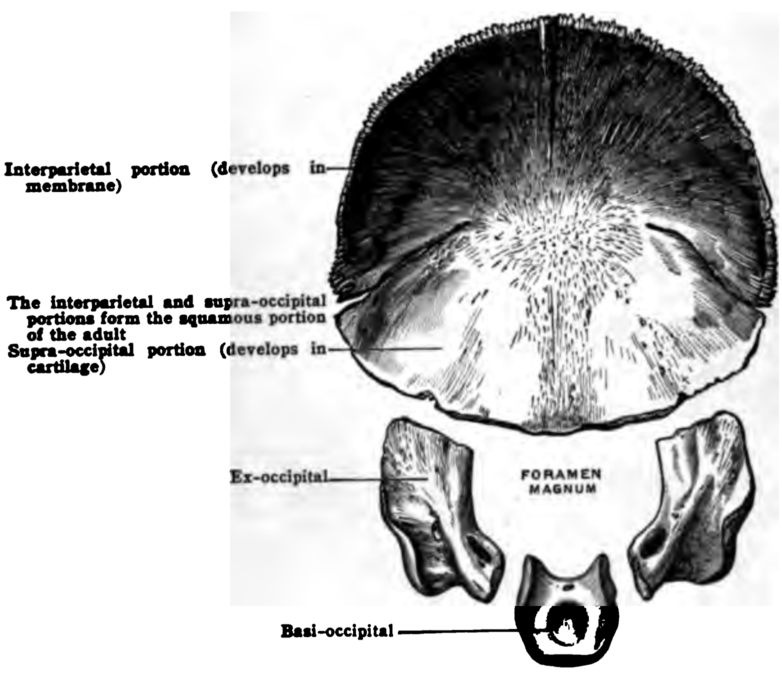
On each side of the middle line are impressions for the insertions of the *longus capitis* (*rectus capitis anterior major*) and *rectus capitis anterior* (*minor*), the impression for the latter being

FIG. 68.—THE FORAMEN MAGNUM AT THE SIXTH YEAR.



nearer to the condyle, and near the foramen magnum this surface gives attachment to the anterior occipito-atlantal ligament. Anteriorly the basilar process articulates by synchondrosis with the body of the sphenoid up to twenty years of age, after which there is complete bony union. Posteriorly it presents a smooth rounded border forming the anterior boundary of the foramen magnum. It gives attachment to the apical odontoid ligament, and above this

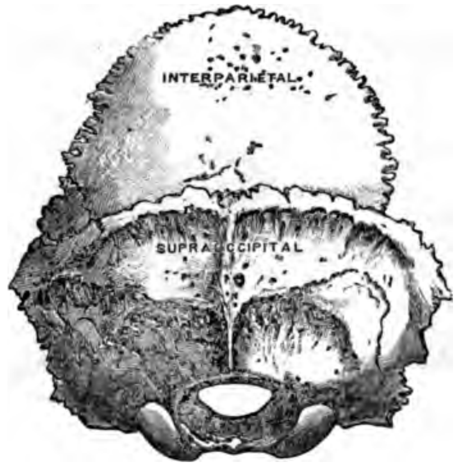
FIG. 69.—THE OCCIPITAL AT BIRTH. (Anterior view.)



to the ascending portion of the crucial ligament. In the occipital bone at the sixth year the lateral extremities of this border are enlarged to form the basilar portion of the condyles. The lateral borders are rough below for articulation with the petrous portion of the temporal bones, but above, on either side of the basilar groove, is a half-groove, which, with a similar half groove on the petrous portion of the temporal bone, lodges the inferior petrosal sinus.

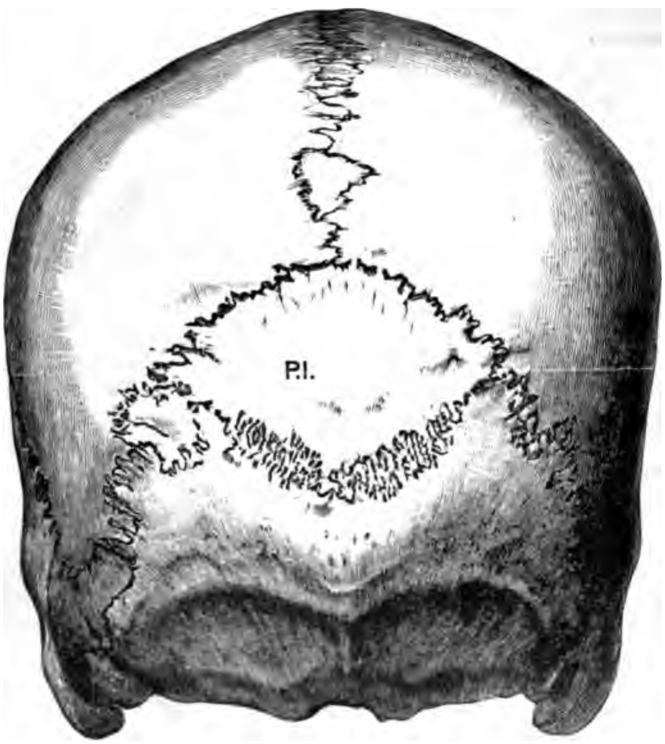
The **foramen magnum** is oval in shape, with its long axis in a sagittal direction. It transmits the medulla oblongata and its membranes, the accessory nerves (spinal portions), the vertebral arteries, the anterior and posterior spinal

FIG. 70.—THE OCCIPITAL WITH A SEPARATE INTERPARIETAL.



arteries, and the tectorial membrane (occipito-axial ligament). It is widest behind, where it transmits the medulla, and is narrower in front, where it is encroached upon by the condyles.

FIG. 71.—SKULL SHOWING A PRE-INTERPARIETAL BONE (P.I.).



Occasionally a facet is present on the anterior margin, forming a *third occipital condyle* for articulation with the dens. Between the condyles and behind the margin of the foramen magnum the posterior occipito-atlantal ligament obtains attachment.

Blood-supply.—The occipital bone receives its blood-supply from the occipital, posterior auricular, middle meningeal, vertebral and the ascending pharyngeal arteries.

Articulations.—The occipital bone is connected by suture with the two parietals, the two temporals, and the sphenoid; the condyles articulate with the atlas, and exceptionally the occipital articulates with the dens of the epistropheus by means of the third occipital condyle.

Ossification.—The occipital bone develops in four pieces. The squamous portion is ossified from four centres, arranged in two pairs, which appear about the eighth week. The upper pair are deposited in membrane, and this part of the squamous portion represents the interparietal bone of many animals. The lower pair, deposited in cartilage, form the true supra-occipital element, and the four parts quickly coalesce near the situation of the future occipital protuberance. For many weeks two deep lateral fissures separate the interparietal and supraoccipital portions, and a membranous space extending from the centre of the squamous portion to the foramen magnum partially separates the lateral portions of the supra-occipital. This space is occupied later by a spicule of bone, and is of interest as being the opening through which the form of hernia of the brain and its meninges, known as occipital meningocele or encephalocele, occurs. The basi-occipital and the two ex-occipitals are ossified each from a single nucleus which appears in cartilage from the eighth to the tenth week.

At birth the bone consists of four parts united by strips of cartilage, and in the squamous portion fissures running in from the upper and lateral angles are still noticeable. The osseous union of the squamous and ex-occipital is completed in the fifth year, and that of the ex-occipitals with the basi-occipital before the seventh year. Up to the twentieth year the basi-occipital is united to the body of the sphenoid by an intervening piece of cartilage, but about that date ossific union begins and is completed in the course of two or three years. Occasionally the interparietal portion remains separate throughout life (fig. 70), forming what has been termed the *inca bone*, or it may be represented by numerous detached ossicles or Wormian bones. In some cases a large Wormian bone, named the pre-interparietal, is found, partly replacing the interparietal bone (fig. 71). A pre-interparietal bone is found in some mammals, and it has occasionally been observed in the human fœtal skull. In fig. 71 the bone is seen in an adult human skull—a distinctly rare condition.

THE PARIETAL

The two **parietal bones** (figs. 72, 73), interposed between the frontal before and the occipital behind, form a large portion of the roof and sides of the cranium. Each parietal bone [os parietale] is quadrilateral in form, convex externally, concave internally, and each presents for examination two surfaces, four borders, and four angles.

The **parietal surface** is smooth and is crossed, just below the middle, by two curved lines known as the **temporal lines.** The superior line gives attachment to the temporal fascia; the lower, frequently the better marked, limits the origin of the *temporal* muscle; whilst the narrow part of the surface enclosed between them is smooth and more polished than the rest. Immediately above the ridges is the most convex part of the bone, termed the **parietal eminence** [tuber parietale], best marked in young bones, and indicating the point where ossification commenced. Of the two divisions on the parietal surface marked off by the temporal lines, the upper is covered by the scalp, and the lower, somewhat striated, affords attachment to the *temporal* muscle. Close to the upper border and near to the occipital angle is a small opening—the **parietal foramen**—which transmits a vein to the superior sagittal (*longitudinal*) sinus.

The **cerebral surface** is marked with depressions corresponding to the cerebral convolutions and by numerous deep furrows, running upward and backward from the sphenoidal angle and the lower border, for the middle meningeal vessels (sinus and artery). A shallow depression running close to the superior border forms, with the one of the opposite side, a channel for the superior sagittal sinus, at the side of which are small irregular pits for the Pacchionian bodies; the pits are usually present in adult skulls, but are best marked in those of old persons. The margins of the groove for the superior sagittal sinus give attachment to the falx cerebri.

Borders.—The **sagittal** or **superior border,** the longest and thickest, is deeply serrated to articulate with the opposite parietal, with which it forms the **sagittal suture.** The **frontal** or **anterior border** articulates with the frontal to form the **coronal suture.** It is deeply serrated and bevelled, so that it is overlapped by the frontal above, but overlaps the edge of that bone below. The **occipital** or **posterior border** articulates with the occipital to form the **lambdoid suture,** and resembles the superior and anterior in being markedly serrated. The **squamosal** or **inferior border** is divided into three portions:—the anterior, thin and bevelled, is overlapped by the tip of the great wing of the sphenoid; the middle portion, arched and also bevelled, is overlapped by the squamous part of the temporal; and the posterior portion, thick and serrated, articulates with the mastoid portion of the temporal bone.

Angles.—The **frontal** or **anterior superior,** almost a right angle, occupies that part of the bone which at birth is membranous and forms part of the anterior

fontanelle. The **sphenoidal** or **anterior inferior** angle is thin and prolonged downward to articulate with the tip of the great wing of the sphenoid. Its inner surface is marked by a deep groove, sometimes converted into a canal for a short

Fig. 72.—The Left Parietal. (Outer surface.)

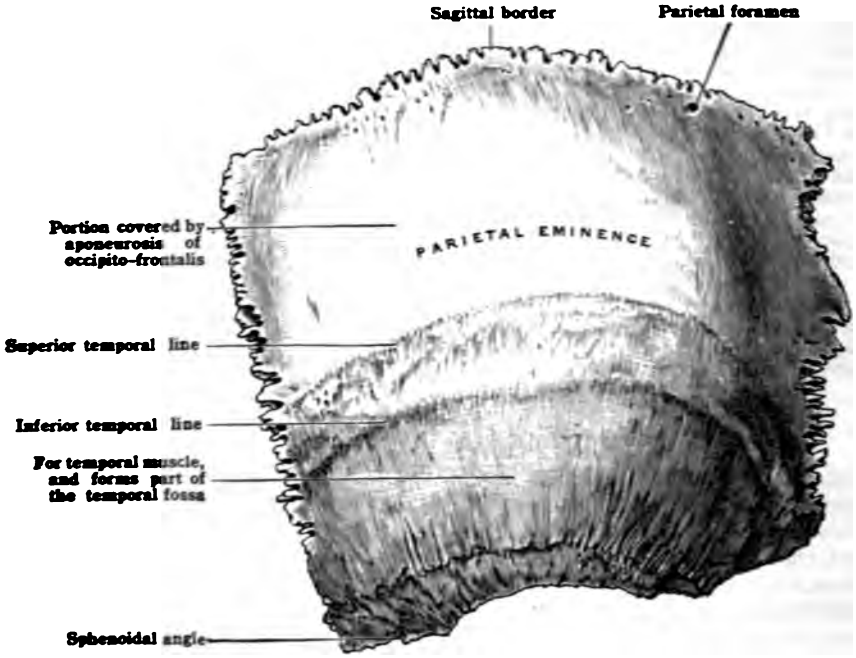
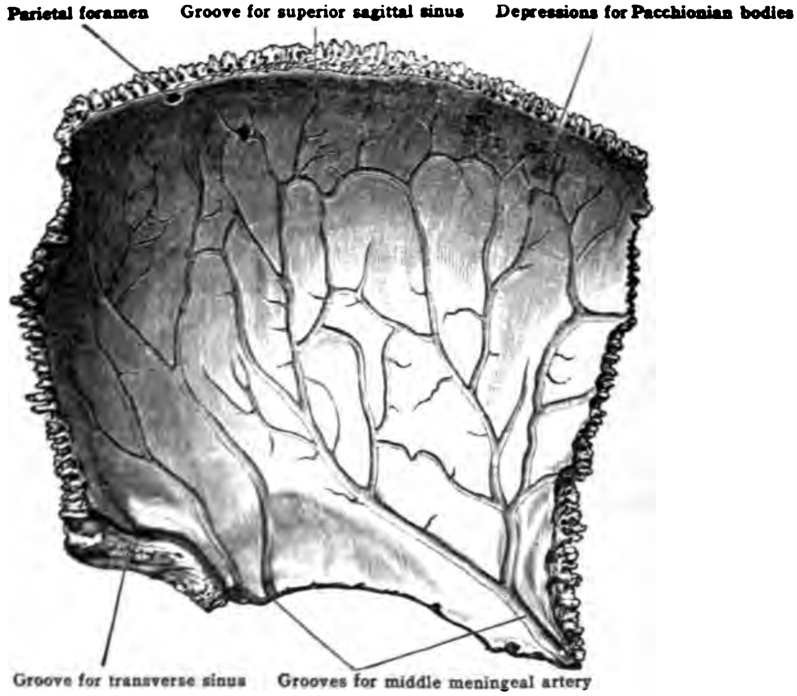


Fig. 73.—The Left Parietal. (Inner surface.)



distance, for the middle meningeal vessels (chiefly for the sinus). The **occipital** or **posterior superior** angle is obtuse and occupies that part which during fœtal life enters into formation of the posterior fontanelle. The **mastoid or posterior**

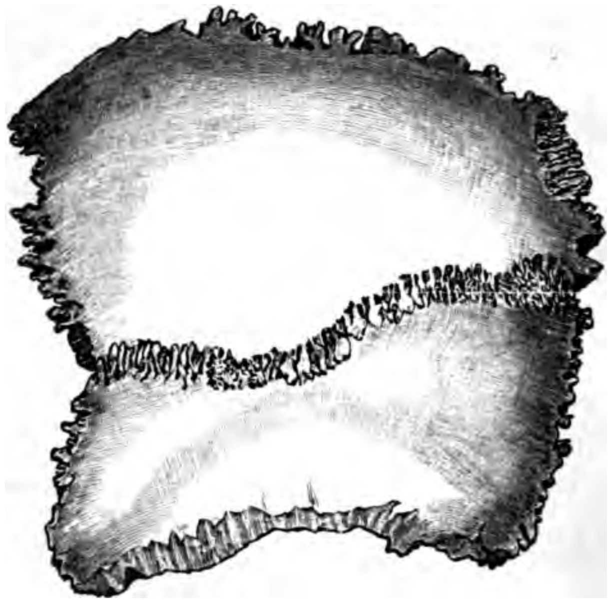
inferior angle is thick and articulates with the mastoid portion of the temporal bone. Its inner surface presents a shallow groove which lodges a part of the **transverse** (lateral) sinus.

Blood-supply.—The parietal bone receives its blood-supply from the middle meningeal, occipital, and supra-orbital arteries.

Articulations.—The parietal articulates with the occipital, frontal, sphenoid, temporal, its fellow of the opposite side, and the epipteric bone when present. Occasionally the temporal and epipteric bones exclude the parietal from articulation with the great wing of the sphenoid.

Ossification.—The parietal ossifies from a single nucleus which appears in the outer layer of the membranous wall of the skull about the seventh week. The ossification radiates in such a way as to leave a cleft at the upper part of the bone in front of the occipital angle, the

FIG. 74.—UNUSUAL FORM OF PARIETAL EXHIBITING A HORIZONTAL SUTURE SEPARATING THE BONE INTO TWO PIECES, UPPER AND LOWER.



cleft of the two side forming a lozenge-shaped space across the sagittal suture known as the **sagittal fontanelle.** This is usually closed about the fifth month of intra-uterine life, but traces may sometimes be recognised at the time of birth, and the parietal foramina are to be regarded as remains of the cleft. According to Dr. A. W. W. Lea, a well-developed sagittal fontanelle is present in 4.4 per cent. of infants at birth. In such cases it closes within the first two months of life, but at times it may remain open for at least eight months after birth and possibly longer.

Rarely the parietal bone is composed of two pieces (fig. 74), one above the other, and separated by an antero-posterior suture (sub-sagittal suture), more or less parallel with the sagittal suture. In such cases the parietal is ossified from two centres of ossification.

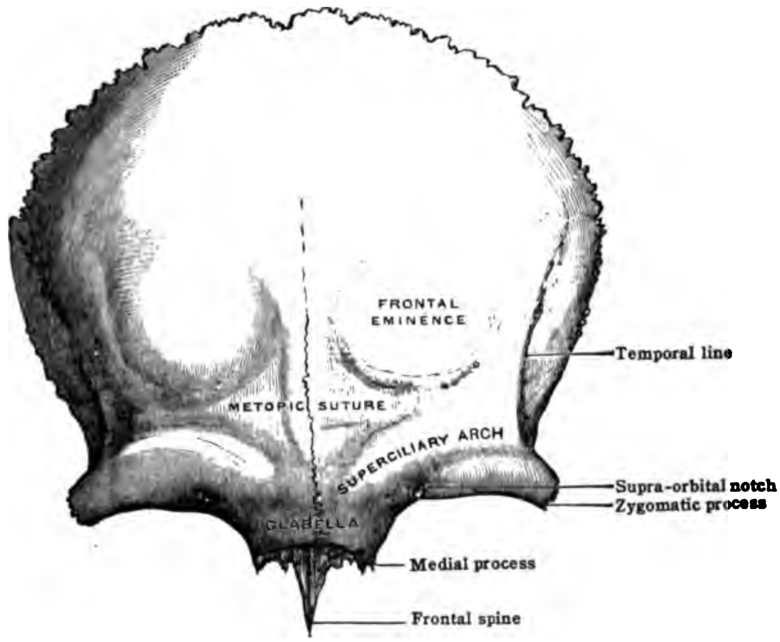
THE FRONTAL

The **frontal bone** [os frontale] closes the cranium in front and is situated above the skeleton of the face. It consists of two portions—a **frontal** (*vertical*) **portion** [squama frontalis], forming the convexity of the forehead, and an **orbital** (*horizontal*) **portion,** which enters into formation of the roof of each orbit.

Frontal (*vertical*) **portion.**—The **frontal surface** is smooth and convex, and usually presents in the middle line above the root of the nose some traces of the suture which in young subjects traverses the bone from the upper to the lower part. This suture, known as the **frontal** or **metopic suture,** indicates the line of junction of the two lateral halves of which the bone consists at the time of birth; in the adult the suture is usually obliterated except at its lowest part. On each side is a rounded elevation, the **frontal eminence** [tuber frontale], very prominent in young bones, below which is a shallow groove, the **sulcus transversus,** separating the frontal eminence from the **superciliary arch.** The latter forms an arched projection above the margin of the orbit and corresponds to an air-cavity within the bone known as the **frontal sinus;** it gives attachment to the *orbicularis oculi* and the *corrugator* muscles. The ridges of the two sides converge toward the

median line, but are separated by a smooth surface called the **glabella** (**nasal** eminence). Below the arch the bone presents a sharp curved margin, the **supra-orbital border,** forming the upper boundary of the circumference of the orbit and separating the frontal from the orbital portion of the bone. At the junction of its medial and intermediate third is a notch, sometimes converted into a foramen, and known as the **supra-orbital notch** or **foramen**; it transmits the supra-orbital nerve, artery, and vein, and at the bottom of the notch is a small opening for a vein of the diploe which terminates in the supra-orbital. Sometimes, a second less marked notch is present, medial to the supra-orbital, and known as the **frontal notch**; it transmits one of the divisions of the supra-orbital nerve. The extremities of the supra-orbital border are directed downward and form the **medial and zygomatic (lateral angular) processes.** The prominent zygomatic process articulates with the zygomatic bone and receives superiorly two well-marked lines which converge somewhat as they curve downward and forward across the bone. These are the **superior** and **inferior temporal lines,** continuous with the

FIG. 75.—THE FRONTAL. (Anterior view.)



temporal lines on the parietal bone, the upper giving attachment to the temporal fascia and the lower to the temporal muscle. Behind the lines is a slight concavity which forms part of the floor of the temporal fossa and gives origin to the *temporal* muscle. The medial angular processes articulate with the lacrimals and form the lateral limits of the **nasal notch,** bounded in front by a rough, semilunar surface which articulates with the upper ends of the nasal bones and the frontal (nasal) processes of the maxillæ.

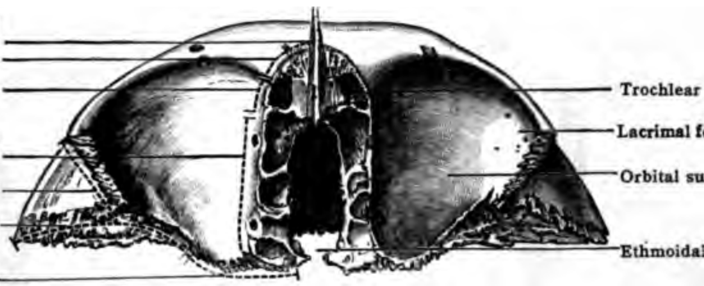
In the concavity of the notch lies the **nasal portion** of the frontal, which projects somewhat beneath the nasal bones and the nasal processes of the maxillæ. It is divisible into three parts: —a median **frontal** (nasal) **spine,** which descends in the nasal septum between the crest of the nasal bones in front and the vertical plate of the ethmoid behind, and, on the posterior aspect of the process, two **alæ,** one on either side of the median ridge from which the frontal (nasal) spine is continued. Each ala forms a small grooved surface which enters into the formation of the roof of the nasal fossa.

The **cerebral surface** presents in the middle line a vertical groove—the **sagittal sulcus**—which descends from the middle of the upper margin and lodges the superior sagittal (longitudinal) sinus. Below, the groove is succeeded by the **frontal crest,** which terminates near the lower margin at a small notch, converted into a foramen by articulation with the ethmoid.

The foramen is called the **foramen cæcum,** and is generally closed below, but sometimes transmits a vein from the nasal fossæ to the superior sagittal (longitudinal) sinus. The frontal crest serves for the attachment of the anterior part of the falx cerebri. On each side of the middle line the bone is deeply concave, presenting depressions for the cerebral convolutions and numerous small furrows which, running medially from the lateral margin, lodge branches of the middle meningeal vessels. At the upper part of the surface, on either side of the frontal sulcus, are some depressions for Pacchionian bodies.

The **horizontal portion** consists of two somewhat triangular plates of bone called the **orbital plates,** which, separated from one another by the **ethmoidal**

FIG. 76.—THE FRONTAL BONE. (Inferior view.)



notch [incisura ethmoidalis], form the greater part of the roof of each orbit. When the bones are articulated, the notch is filled up by the cribriform plate of the ethmoid, and the half-cells on the upper surface of the lateral mass of the ethmoid are completed by the depressions or half-cells which occupy the irregular margins of the notch. Traversing these edges transversely are two grooves which complete, with the ethmoid, the **anterior** and **posterior ethmoidal canals.** The anterior transmits the anterior ethmoidal nerve and vessels; the posterior transmits the posterior ethmoidal nerve and vessels, and both canals open on the medial wall of the orbit. Farther forward, on either side of the nasal spine, are the openings of the **frontal sinuses,** two irregular cavities which extend within

FIG. 77.—THE FRONTAL BONE AT BIRTH.

the bone for a variable distance and give rise to the superciliary arches (ridges). Each is lined by mucous membrane and communicates with the nasal fossa by means of a passage called the infundibulum.

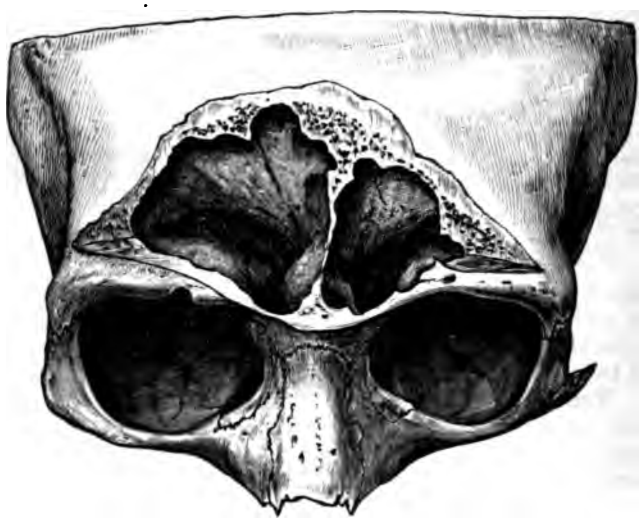
The **inferior surface** of each orbital plate, smooth and concave, presents immediately behind the lateral angular process the **lacrimal fossa,** for the lacrimal gland. Close to the medial angular process is a depression called the **trochlear fossa** [fovea trochlearis], which gives attachment to the cartilaginous pulley for the *superior oblique* muscle. The **superior surface** of each plate is convex and strongly marked by eminences and depressions for the convolutions on the orbital surface of the cerebrum.

Borders.—The articular border of the frontal portion (**parietal margin**) forms a little more than a semicircle. It is thick, strongly serrated, and bevelled so as to overlap the parietal above and to be overlapped by the edge of that bone below. The border is continued inferiorly into a triangular rough surface on either side, which articulates with the great wing of the sphenoid. The posterior border of the orbital portion is thin and articulated with the lesser wing of the sphenoid.

Blood-supply.—The blood-vessels for the supply of the vertical portion are derived from the frontal and supra-orbital arteries, which enter on the outer surface, and from the middle and small meningeal, which enter on the cerebral surface. The horizontal portion receives branches from the ethmoidal, and other branches of the ophthalmic, as well as from the meningeal.

Articulations.—The frontal articulates with the parietal, sphenoid, ethmoid, lacrimal, zygomatic (malar), maxilla, and nasal bones. Also, with the epipteric bones when present, and occasionally with the squamous portion of the temporal, and with the sphenoidal concha when it reaches the orbit.

Fig. 78.—Unusually Large Frontal Sinuses.



Ossification.—The frontal is ossified from two nuclei deposited in the outer layer of the membranous wall of the cranium, in the situations ultimately known as the frontal eminences. These nuclei appear about the eighth week, and ossification spreads quickly through the membrane. At birth the bones are quite distinct, but subsequently they articulate with each other in the median line to form the metopic suture. In the majority of cases the suture is obliterated by osseous union, which commences about the second year, though in a few cases the bones remain distinct throughout life.

After the two halves of the bone have united, osseous material is deposited at the lower end of the metopic suture to form the frontal spine, which is one of the distinguishing features of the human frontal bone. The spine appears about the twelfth year, and soon consolidates with the frontal bone above. Accessory nuclei are sometimes seen between this bone and the lacrimal and may persist as Wormian ossicles.

The frontal sinuses appear about the seventh year as prolongations upward from the hiatus semilunaris and increase in size up to old age. As they grow they extend in three directions, viz., upward, laterally, and backward along the orbital roof. A bony septum, usually complete, separates the sinuses of the two sides, and they are larger in the male than in the female. The superciliary arches are not altogether reliable guides as to the size of the sinuses, since examples are seen in which the arches are low and the sinuses large. In fig. 78 an example of unusually large sinuses is figured, illustrating the extension upward, laterally, and backward.

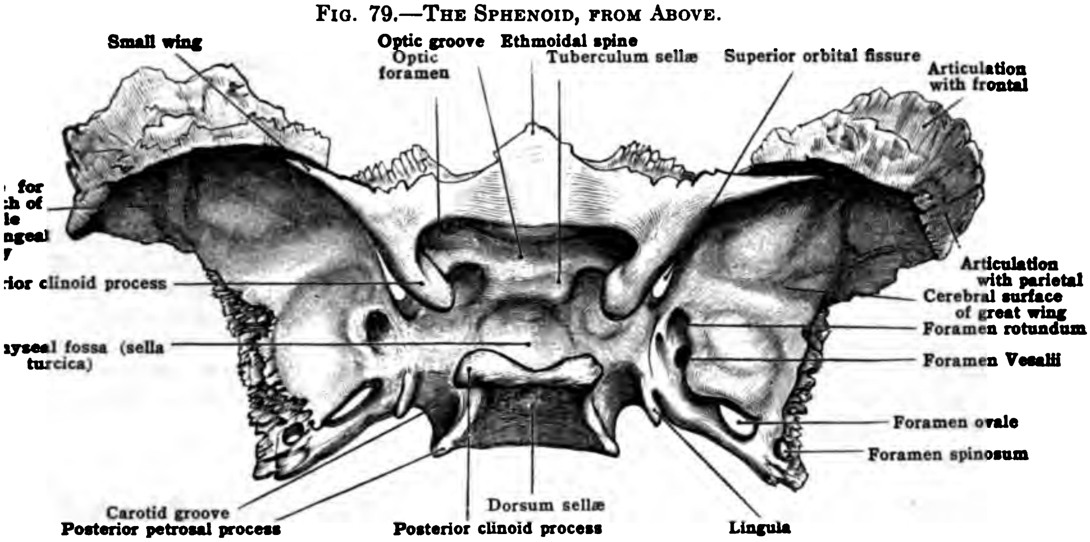
THE SPHENOID

The **sphenoid** [os sphenoidale] (figs. 79, 80, 81, 82) is situated in the base of the skull and takes part in the formation of the floor of the anterior, middle, and posterior cranial fossæ, of the temporal and nasal fossæ, and of the cavity of the orbit. It is very irregular in shape and is described as consisting of a central part or **body**, two pairs of lateral expansions called the **great** and **small wings**, and a pair of processes which project downward, called the **pterygoid processes.**

The **body**, irregularly cuboidal in shape, is hollowed out into two large cavities known as the **sphenoidal sinuses**, separated by a thin **sphenoidal septum** and opening in front by two large apertures into the nasal fossæ. The **superior sur-**

face presents the following points for examination: In front is seen a prominent spine, the **ethmoidal spine,** which articulates with the hinder edge of the cribriform plate of the ethmoid. The surface behind this is smooth and frequently presents two longitudinal grooves, one on either side of the median line, for the olfactory bulbs; it is limited posteriorly by a ridge, the **limbus sphenoidalis,** which forms the anterior border of the narrow transverse **optic groove** [sulcus chiasmatis], above and behind which lies the optic commissure. The groove terminates on each side in the **optic foramen,** which perforates the root of the small wing and transmits the optic nerve and the ophthalmic artery. Behind the optic groove is the **tuberculum sellæ,** indicating the line of junction of the two parts of which the body is formed (pre- and post-sphenoid); and still further back, a deep depression, the **hypophyseal fossa** [sella turcica], which lodges the hypophysis cerebri. The floor of the fossa presents numerous foramina for blood-vessels, and at birth the superior orifice of a narrow passage called the **basi-pharyngeal canal** opens on the tuberculum. The posterior boundary of the fossa is formed by a quadrilateral plate of bone, the **dorsum sellæ** (dorsum

Fig. 79.—The Sphenoid, from Above.



ephippii), the posterior surface of which is sloped in continuation with the basilar groove of the occipital bone. The superior angles of the plate are surmounted by the **posterior clinoid processes,** which give attachment to the tentorium cerebelli and the interclinoid ligaments. Below the clinoid process, on each side of the dorsum sellæ (sometimes at the suture between the sphenoid and apex of petrosal), a notch is seen, converted into a foramen by the dura mater, for the passage of the sixth cranial nerve, and at the inferior angle the **posterior petrosal process,** which articulates with the apex of the petrous portion of the temporal bone, forming the inner boundary of the **foramen lacerum.** The dorsum sellæ is slightly concave posteriorly (the clivus) and supports the pons Varolii and the basilar artery.

The **inferior surface** presents in the middle line a prominent ridge known as the **rostrum,** which is received into a deep depression between the alæ of the vomer. On each side is the **vaginal process** of the medial pterygoid plate, directed horizontally and medially, which, with the alæ of the vomer, covers the greater part of this surface. The remainder is rough and clothed by the mucous membrane of the roof of the pharynx.

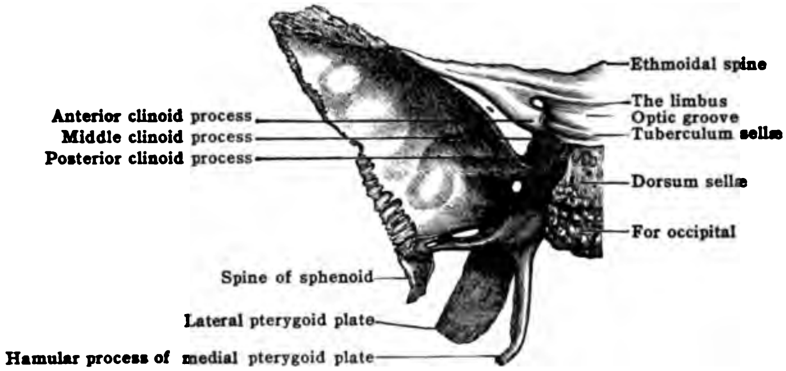
The **anterior surface** is divided into two lateral halves by the **sphenoidal crest,** a vertical ridge of bone continuous above with the ethmoidal spine, below with the rostrum, and articulating in front with the perpendicular plate of the ethmoid. The surface on each side presents a rough lateral margin for articulation with the lateral mass of the ethmoid and the orbital process of the palate bone. Elsewhere it is smooth, and enters into the formation of the roof of the

nasal fossæ, presenting superiorly the irregular apertures of the sphenoidal sinuses.

The body is not hollowed until after the sixth year, but from that time the sinuses increase in size as age advances. Except for the apertures just mentioned, they are closed below and in front by the two **sphenoidal conchæ** (turbinate bones), originally distinct, but in the adult usually incorporated with the sphenoid.

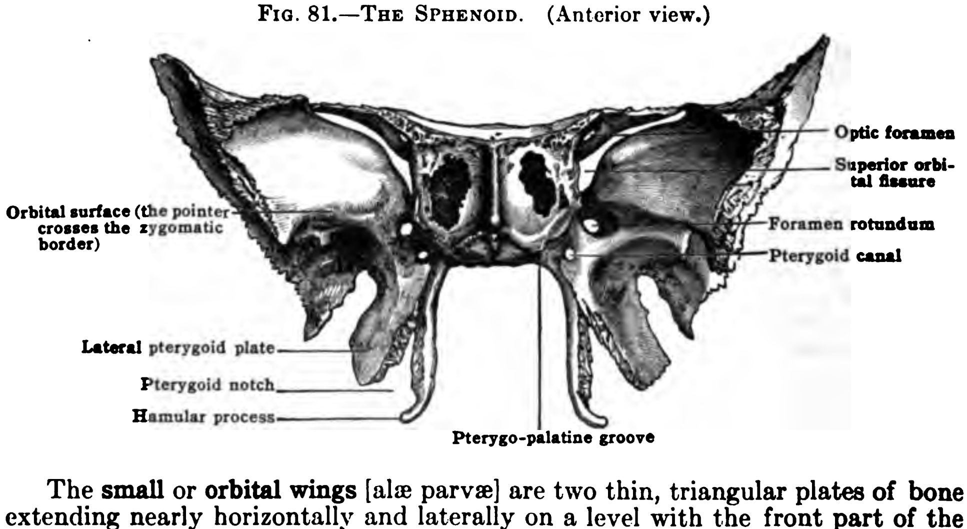
The **posterior surface** is united to the basilar process of the occipital, up to the twentieth year, by a disc of hyaline cartilage forming a sÿnchondrosis, but afterward this becomes ossified and the two bones then form one piece.

Fig. 80.—The Left Half of the Sphenoid.



The **lateral surface** of the body gives attachment to the two **wings**, and its fore part is free where it forms the medial boundary of the superior orbital fissure and the posterior part of the medial wall of the orbit. Above the line of attachment of the great wing is a broad groove which lodges the internal carotid artery and the cavernous sinus, called the **carotid** groove. It is deepest where it curves behind the root of the process, and this part is bounded along its lateral margin by a slender ridge of bone named the **lingula,** which projects backward in the angle between the body and the great wing.

Fig. 81.—The Sphenoid. (Anterior view.)



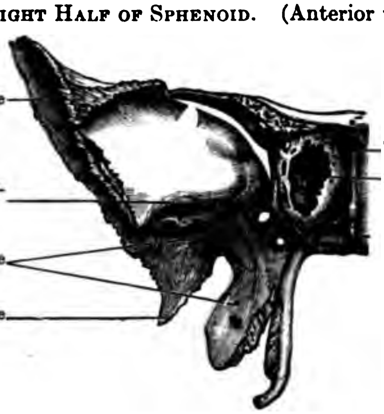
The **small** or **orbital wings** [alæ parvæ] are two thin, triangular plates of bone extending nearly horizontally and laterally on a level with the front part of the upper surface of the body. Each arises medially by two processes or roots, the upper thin and flat, the lower thick and rounded.

Near the junction of the lower root with the body is a small tubercle for the attachment of the common tendon of three ocular muscles—viz., the *superior, medial,* and upper head of *lateral rectus*—and between the two roots is the **optic foramen.** The lateral extremity, slender and pointed, approaches the great wing, but, as a rule, does not actually touch it. The superior surface, smooth and slightly concave, forms the posterior part of the anterior fossa of the cranium. The inferior surface constitutes a portion of the roof of each orbit and overhangs

the **superior orbital** (or **sphenoidal**) **fissure,** the elongated opening between the small and great wings. The anterior border is serrated for articulation with the orbital plate of the frontal, and the posterior border, smooth and rounded, is received into the Sylvian fissure of the cerebrum. Moreover, the posterior border forms the boundary between the anterior and middle cranial fossæ and is prolonged at its medial extremity to form the **anterior clinoid process,** which gives attachment to the tentorium cerebelli and the interclinoid ligaments. Between the tuberculum sellæ and the anterior clinoid process is a semicircular notch which represents the termination of the carotid groove. It is sometimes converted into a foramen, the **carotico-clinoid foramen,** by a spicule of bone which bridges across from the anterior clinoid to the **middle clinoid process;** the latter is a small tubercle frequently seen on each side, in front of the hypophyseal fossa, and slightly posterior to the tuberculum sellæ; the foramen transmits the internal carotid artery, and the spicule of bone which may complete the foramen is formed by ossification of the carotico-clinoid ligament.

The **great** or **temporal wings** [alæ magnæ], arising from the lateral surface of the body, extend laterally and then upward and forward. The posterior part is placed horizontally and projects backward into the angle between the squamous and petrous portions of the temporal bone. From the under aspect of its pointed extremity the **spine,** which is grooved medially by the chorda tympani nerve (Lucas), projects downward. The spine serves for the attachment of the spheno-mandibular ligament and a few fibres of the *tensor veli palatini.* Each wing presents for examination four surfaces and four borders.

FIG. 82.—RIGHT HALF OF SPHENOID. (Anterior view.)



The **cerebral** or **superior surface** is smooth and concave. It enters into the formation of the middle cranial fossa, supports the temporo-sphenoidal lobe of the cerebrum, and presents several foramina. At the anterior and medial part is the **foramen rotundum** for the second division of the fifth nerve, and behind and lateral to it, near the posterior margin of the great wing, is the large **foramen ovale,** transmitting the third division of the fifth, the small meningeal artery, and an emissary vein from the cavernous sinus.

Behind and lateral to the foramen ovale is the small circular **foramen spinosum,** sometimes incomplete, for the passage of the middle meningeal vessels, and the recurrent branch of the third division of the fifth. Between the foramen ovale and the foramen rotundum is the inconstant **foramen Vesalii,** which transmits a small emissary vein from the cavernous sinus; and on the plate of bone, behind and medial to the foramen ovale (spheno-petrosal lamina), a minute canal is occasionally seen—the **canaliculus innominatus**—through which the small superficial petrosal nerve escapes from the skull. When the canaliculus is absent, the nerve passes through the foramen ovale.

The **anterior surface** looks medially and forward and consists of two divisions—a quadrilateral or **orbital** surface, which forms the chief part of the lateral wall of the orbit, and a smaller, inferior or **spheno-maxillary** surface, situated above the pterygoid process and perforated by the foramen rotundum; this inferior part forms the posterior wall of the pterygo-palatine fossa.

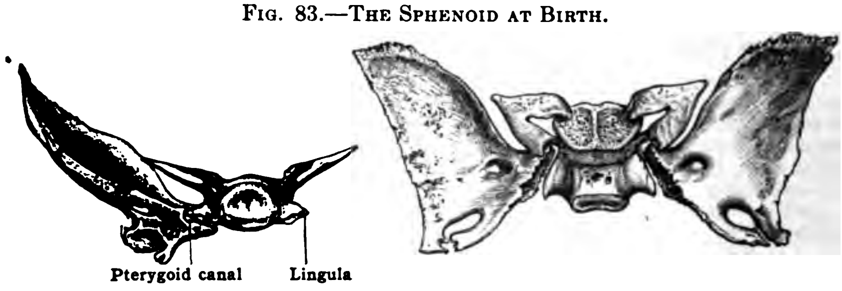
The lateral or **squamo-zygomatic surface** is divided by a prominent **infra-temporal ridge** into a superior portion, which forms part of the temporal fossa and affords attachment to the *temporal* muscle, and an inferior part, which looks downward into the zygomatic fossa and gives attachment to the *external pterygoid* muscle; the inferior part joins the lateral surface of the lateral pterygoid plate, and presents the inferior orifices of the foramen ovale, foramen spinosum, and foramen of Vesalius.

Borders.—The **posterior border** extends from the body to the spine. By its lateral third it articulates with the petrous portion of the temporal bone, whilst the medial two-thirds form the anterior boundary of the foramen lacerum. The **squamosal border** is serrated behind and bevelled in front for articulation with the squamous portion of the temporal bone, whilst its upper extremity, or summit, is bevelled on its inner aspect, for the anterior inferior angle of the parietal. Immediately in front of the upper extremity is a rough, triangular, sutural area for the frontal, the sides of which are formed by the upper margins of the superior, anterior, and lateral surfaces respectively. The **zygomatic** or **anterior border** separates the orbital and temporal surfaces and articulates with the zygomatic, and by its lower angle, in many skulls, also with the maxilla. Below the anterior border is a short horizontal ridge, non-articular, which separates the spheno-maxillary and zygomatic surfaces. Above and medially, where the orbital and cerebral surfaces meet, is the sharp **medial border**, which forms the lower boundary of the **superior orbital fissure**, serving for the passage of the third, fourth, three branches of the first division of the fifth, and the sixth cranial nerves, the orbital branch of the middle meningeal artery, a recurrent branch from the lacrimal artery, some twigs from the cavernous plexus of the sympathetic, and one or two ophthalmic veins. Near the middle of the border is a small tubercle for the origin of the lower head of the *lateral rectus* muscle.

The **pterygoid processes** project downward from the junction of the body and the great wings. Each consists of two plates, one shorter and broader, the **lateral pterygoid plate** [lamina lateralis], the other longer and narrower, the **medial pterygoid plate** [lamina medialis]. They are united in front, but diverge behind so as to enclose between them the **pterygoid fossa** in which lie the *internal pterygoid* and *tensor palati* muscles. The lateral pterygoid plate is turned a little laterally and by its lateral surface, which looks into the zygomatic fossa, affords attachment to the *external pterygoid* muscle, whilst from its medial surface the *internal pterygoid* takes origin.

The posterior border of the lateral pterygoid plate frequently presents one or more bony projections, which represent ossified parts of the pterygo-spinous ligaments, and occasionally one may extend across to the spine and complete the bony boundary of the pterygo-spinous foramen. The medial pterygoid plate is prolonged below into a slender, hook-like or **hamular process**, smooth on the under aspect for the tendon of the *tensor palati*, which plays round it. Superiorly, the medial plate extends medially on the under surface of the body, forming the **vaginal process**, which articulates with the ala of the vomer and the sphenoidal process of the palate. The vaginal process presents, on the under surface, a small groove which, with the sphenoidal process of the palate, forms the **pharyngeal canal** for the transmission of branches of the spheno-palatine vessels and ganglion. The medial surface of the medial pterygoid plate forms part of the lateral boundary of the nasal fossa, and the lateral surface, the medial boundary of the pterygoid fossa. The posterior border presents superiorly a well-marked prominence, the **pterygoid tubercle**, above and to the lateral side of which is the posterior orifice of the pterygoid canal. The latter pierces the bone in the sagittal direction at the root of the medial pterygoid plate and transmits the Vidian vessels and nerve. Some distance below the tubercle is a projection, called the **processus tubarius**, which supports the cartilage of the tuba auditiva (Eustachian tube). From the lower third of the posterior border and from the hamular process, the *superior constrictor* of the pharynx takes origin, and from the depression known as the **scaphoid fossa**, situated in the upper part of the recess between the two pterygoid plates, the *tensor palati* arises.

FIG. 83.—THE SPHENOID AT BIRTH.



In front, the two plates are joined above, but diverge below, leaving a gap—the **pterygoid notch**—occupied, in the articulated skull, by the pyramidal process of the palate. Superiorly, they form a triangular surface which looks into the pterygo-palatine fossa and presents the anterior orifice of the pterygoid canal. The anterior border of the medial pterygoid plate articulates with the posterior border of the vertical plate of the palate.

Blood-supply.—The sphenoid is supplied by branches of the middle and small meningeal arteries, the deep temporal and other branches of the internal maxillary artery—viz., the Vidian and spheno-palatine. The body of the bone also receives twigs from the internal carotid.

Articulations.—The sphenoid articulates with all the bones of the cranium—viz., occipital,

parietal, frontal, ethmoid, temporal, and sphenoidal conchæ. Also with the palate, vomer, zygomatic, epipteric bone when present, and occasionally with the maxilla.

Ossification.—The sphenoid is divided, up to the seventh or eighth month of intra-uterine life, into an anterior or **pre-sphenoid** portion, including the part of the body in front of the tuberculum sellæ and the small wings, and a **post-sphenoid** portion, the part behind the tuberculum sellæ including the hypophyseal fossa and the great wings. The two portions of the body join together before birth, but in many animals the division is persistent throughout life.

The pre-sphenoid portion ossifies in cartilage from four centres, one of which gives rise to each lesser wing (orbito-sphenoid) and a pair to the body of the pre-sphenoid.

In the formation of the post-sphenoidal portion both cartilage and membrane bone participate, the pterygoid plates being formed in membrane, while the rest of the portion, together with the hamular process, ossifies from cartilage. (Fawcett.) At about the eighth week a

FIG. 84.—THE JUGUM SPHENOIDALE.

centre appears at the base of each greater wing (ali-sphenoid), and at about the same time a pair of centres appear in the body (basi-sphenoid) and later one in each **lingula** (**sphenotic**). The medial pterygoid plates are pre-formed in cartilage, in which a centre appears for the hamular process, but the rest of the plate is formed from membrane bone which invests the cartilage. The lateral plate is formed in membrane and a considerable part of the greater wing is also membranous in origin (see epipteric bone).

At birth the bone consists of three pieces. The median piece includes the basi-sphenoid and lingulæ, conjoined with the pre-sphenoid, carrying the orbito-sphenoids.

The two lateral pieces are the ali-sphenoids, carrying the medial pterygoid plates. The dorsum sellæ is cartilaginous. A canal, known as the **basi-pharyngeal canal**, extends into the

FIG. 85.—THE INFERIOR SURFACE OF PRE-SPHENOID AT THE SIXTH YEAR.

body from the sella turcica and sometimes reaches its under surface. It contains a process of dura mater, and represents the remains of the canal in the base of the cranium, through which the diverticulum of Rathke extended upward to form part of the hypophysis.

The great wings are joined to the lingulæ by cartilage, but in the course of the first year bony union takes place. About the same time the orbito-sphenoids meet and fuse in the middle line to form the **jugum sphenoidale**, which thus excludes the anterior part of the pre-sphenoid from the cranial cavity. For some years the body of the pre-sphenoid is broad and rounded inferiorly (fig. 85). The posterior clinoid processes chondrify separately, a fact which throws some light on the occasional absence of these processes.

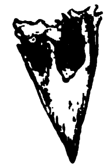
THE SPHENOIDAL CONCHÆ

The **sphenoidal conchæ** (or **turbinate bones**; bones of Bertin) (figs. 86, 87) may be obtained as distinct ossicles about the fifth year, and resemble in shape two hollow cones flattened in three planes. At this date each is wedged in between the under surface of the pre-sphenoid and the orbital and sphenoidal processes of the palate bone, with the apex of the cone directed backward as far as the vaginal process of the medial pterygoid plate. Of its three surfaces, the lateral is in relation with the pterygo-palatine fossa, and occasionally extends upward between the sphenoid and the lamina papyracea of the ethmoid, to appear on the medial wall of the orbit (fig. 105). The inferior surface forms the upper boundary of the spheno-palatine foramen and enters into formation of the posterior part of the roof of the nasal fossa. The

superior surface lies flattened against the under surface of the pre-sphenoid, whilst the base of the cone is in contact with the lateral mass of the ethmoid.

The deposits of earthy matter from which the sphenoidal conchæ are formed appear at the fifth month. At birth each forms a small triangular lamina in the perichondrium of the ethmo-vomerine plate near its junction with the presphenoid, and partially encloses a small recess from the mucous membrane of the nose, which becomes the sphenoidal sinus. By the third year the bone has surrounded the sinus, forming an osseous capsule, conical in shape, the circular orifice which represents the base becoming the sphenoidal foramen. As the cavity enlarges the medial wall is absorbed, and the medial wall of the sinus is then formed by the pre-sphenoid.

FIG. 86.—THE SPHENOIDAL CONCHA AT THE SIXTH YEAR.



The bones are subsequently ankylosed in many skulls with the ethmoid, whence they are often regarded as parts of that bone. More frequently they fuse with the pre-sphenoid, and less frequently with the palate bones. After the twelfth year they can rarely be separated from the skull without damage. In many disarticulated skulls they are so broken up that a portion is found on the sphenoid, fragments on the palate bones, and the remainder attached to the ethmoid. Sometimes, even in old skulls, they are represented by a very thin triangular plate on each side of the rostrum of the sphenoid (fig. 87).

FIG. 87.—THE SPHENOIDAL CONCHÆ FROM AN OLD SKULL.

THE EPIPTERIC AND WORMIAN BONES

The **epipterics** are scale-like bones which occupy the antero-lateral **fontanelles**. Each epipteric bone is wedged between the squamo-zygomatic portion of the temporal, frontal, great wing of sphenoid, and the parietal, and is present in most skulls between the second and fifteenth year. After that date it may persist as a separate ossicle, or unite with the sphenoid, the frontal, or the squamo-zygomatic. The epipteric bone is pre-formed in membrane, and appears as a series of bony granules in the course of the first year.

The **Wormian** or **sutural bones** [ossa suturarum] are small, irregularly shaped ossicles, often found in the sutures of the cranium, especially those in relation with the parietal bones. They sometimes occur in great numbers; as many as a hundred have been counted in one skull. They are rarely present in the sutures of the face.

THE TEMPORAL BONE

The **temporal bone** [os temporale], situated at the side and the base of the cranium, contains the organ of hearing and articulates with the lower jaw. It is usually divided into three parts—viz., the **squamous portion,** forming the anterior and superior part of the bone, thin and expanded and prolonged externally into the zygomatic process; the **mastoid portion,** the thick conical posterior part, behind the external aperture of the ear; and a pyramidal projection named the **petrous portion,** situated in a plane below and to the medial side of the two parts already mentioned, and forming part of the base of the skull.

When it is considered in reference to its mode of development, the temporal bone is found to be built up of three parts (figs. 88, 89, 90), which, however, do not altogether correspond to the arbitrary divisions of the adult bone. The three parts are named **squamosal, petrosal,**

and tympanic, and a knowledge of their arrangement in the early stages of growth greatly facilitates the study of the fully formed bone.

The more important division of the temporal bone is the petrous portion. It is pyramidal in shape, and contains the essential part of the organ of hearing,

FIG. 88.—THE TEMPORAL BONE AT BIRTH.

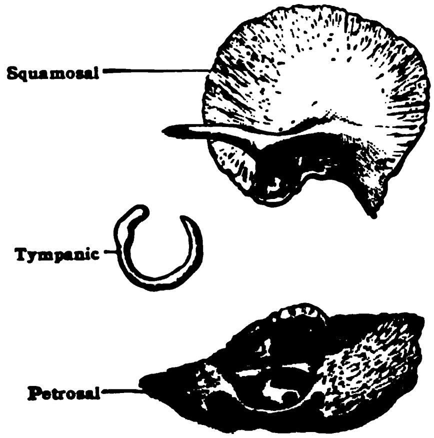


FIG. 89.—TEMPORAL BONE AT BIRTH. (Inner view.)

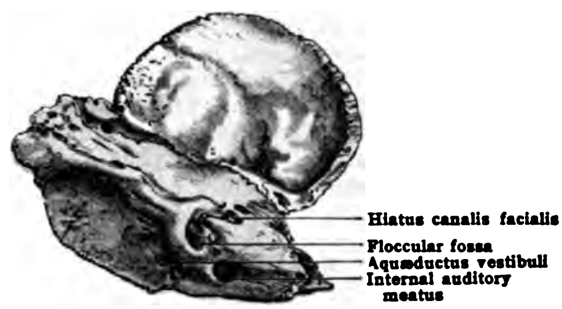
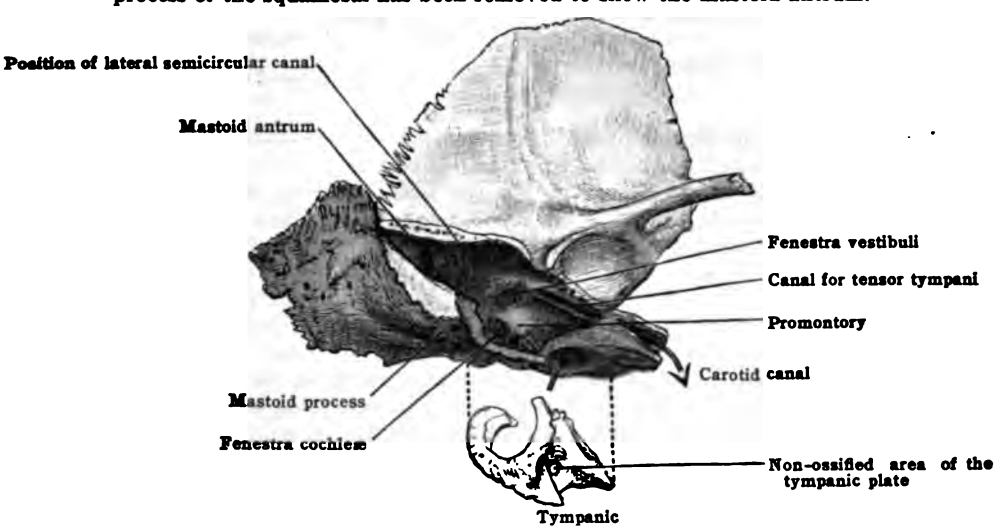


FIG. 90.—THE TEMPORAL BONE AT BIRTH. (Outer view.)

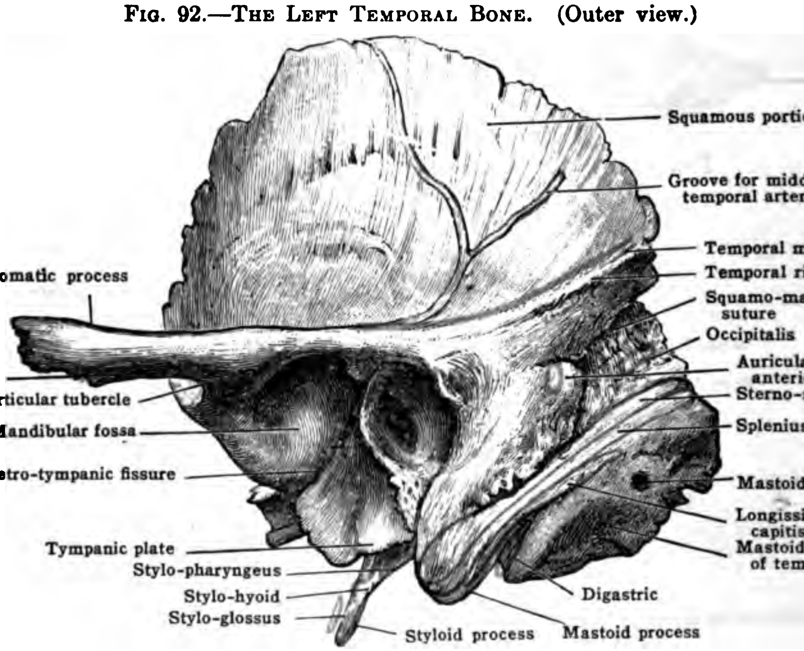
FIG. 91.—RIGHT TEMPORAL BONE AT ABOUT SIX YEARS.
The tympanic plate has been separated and drawn below. A portion of the post-auditory process of the squamosal has been removed to show the mastoid antrum.



around which it is developed as a cartilaginous capsule. This is known as the **periotic capsule** or **petrosal** element, and its **base** abuts on the outer aspect of the

cranium, where it forms a large part of the so-called mastoid portion of the temporal bone. Besides containing the internal ear, it bears on its cranial side a foramen for the seventh and eighth cranial nerves (internal auditory meatus), and on its outer side two openings—the fenestra vestibuli and fenestra cochleæ (fig. 91). The **squamosal** is a superadded element and is formed as a membrane bone in the lateral wall of the cranium. It is especially developed in man in consequence of the large size of the brain, and forms the squamous division of the adult bone, and by a triangular shaped process which is prolonged behind the aperture of the ear it also contributes to the formation of the mastoid portion. It is obvious, therefore, that the mastoid is not an independent element, but belongs in part to the petrous, and in part to the squamous. The **tympanic** portion, also superadded, is a ring of bone developed in connection with the external auditory meatus, and eventually forms a plate constituting part of the bony wall of this passage. These three parts are easily separable at birth, but eventually become firmly united to form a single bone which affords little trace of its complex origin. Lastly a process of bone, developed in the second visceral arch, coalesces with the under surface of the temporal bone and forms the **styloid process.**

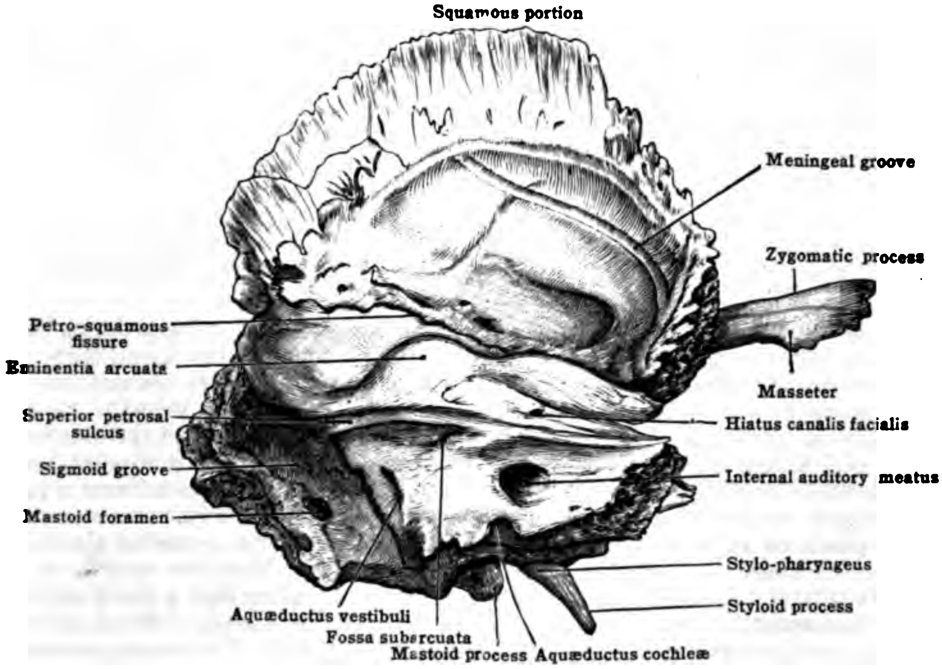
Fig. 92.—The Left Temporal Bone. (Outer view.)



The **squamous portion** [squama temporalis] is flat, scale-like, thin, and translucent. It is attached almost at right angles to the petrous portion, forms part of the side wall of the skull and is limited above by an uneven border which describes about two-thirds of a circle. The outer surface is smooth, slightly convex near the middle, and forms part of the temporal fossa. Above the external auditory meatus it presents a nearly vertical groove for the middle temporal artery. Connected with its lower part is a narrow projecting bar of bone known as the **zygomatic process.** At its base the process is broad, directed laterally, and flattened from above downward. It soon, however, becomes twisted on itself and runs forward, almost parallel with the squamous portion. This part is much narrower and compressed laterally so as to present medial and lateral surfaces with upper and lower margins. The lateral surface is subcutaneous; the medial looks toward the temporal fossa and gives origin to the *masseter* muscle. The lower border is concave and rough for fibres of the same muscle, whilst the upper border, thin and prolonged further forward than the lower, receives the temporal fascia. The extremity of the process is serrated for articulation with the zygomatic bone. At its base the zygomatic process presents three roots—anterior, middle, and posterior.

The anterior, continuous with the lower border, is short, broad, convex, and directed medially to terminate in the **articular tubercle,** which is covered with cartilage in the recent state, for articulation with the condyle of the lower jaw. The middle root, sometimes very prominent, forms the **post-glenoid process.** It separates the articular portion of the mandibular fossa from the external auditory meatus and is situated immediately in front of the **petro-tympanic** (**Glaserian**) **fissure.** The posterior root, prolonged from the upper border, is strongly marked and extends backward as a ridge above the external auditory meatus. It is called the **temporal ridge** (supra-mastoid crest), and marks the arbitrary line of division between the squamous and mastoid portions of the adult bone. It forms part of the posterior boundary of the temporal fossa, from which, as well as from the ridge, fibres of the *temporal* muscle arise. Where the anterior root joins the zygomatic process is a slight tubercle—the **preglenoid tubercle**—for the attachment of the temporo-mandibular ligament, and between the anterior and middle roots is a deep oval depression, forming the part of the mandibular fossa for the condyle of the lower jaw. The **mandibular fossa** is a considerable hollow, bounded in front by the articular tubercle and behind by the tympanic plate which separates it from the external auditory meatus. It is divided into two parts by a narrow slit—the **petro-tympanic** (**Glaserian**) **fissure.** The anterior part [facies articularis], which belongs to the squamous portion, is articular, and, like the articular tubercle, is coated with cartilage. The posterior

FIG. 93.—THE LEFT TEMPORAL BONE. (Seen from the inner side and above.)



part, formed by the tympanic plate, is non-articular and lodges a lobe of the parotid gland. Immediately in front of the articular tubercle is a small triangular surface which enters into the formation of the roof of the zygomatic fossa.

The inner or *cerebral surface* of the squamous portion is marked by furrows for the convolutions of the brain and grooves for the middle meningeal vessels. At the upper part of the surface the inner table is deficient and the outer table is prolonged some distance upward, forming a thin scale, with the bevelled surface looking inward to overlap the corresponding edge of the parietal. Anteriorly the border is thicker, serrated, and slightly bevelled on the outer side for articulation with the posterior border of the great wing of the sphenoid. Posteriorly it joins the rough serrated margin of the mastoid portion to form the parietal notch. The line separating the squamous from the petrous portion is indicated at the lower part of the inner surface by a narrow cleft, the internal **petro-squamous suture,** the appearance of which varies in different bones according to the degree of persistence of the original line of division.

The **mastoid portion** [pars mastoidea] is rough and convex. It is bounded above by the temporal ridge and the parieto-mastoid suture; in front, by the external auditory meatus and the **tympano-mastoid** fissure; and behind, by the suture between the mastoid and occipital. As already pointed out, it is formed by the squamous portion in front and by the base of the petrosal behind, the line of junction of the two component parts being indicated on the outer surface by the **external petro-squamous suture** (squamo-mastoid). The appearance of the suture varies, being in some bones scarcely distinguishable, in others, a series

of irregular depressions, whilst occasionally it is present as a well-marked fissure (fig. 92) directed obliquely downward and forward. The mastoid portion is prolonged downward behind the external acoustic meatus into a nipple-shaped projection, the **mastoid process,** the tip of which points forward as well as downward. The process is marked, on its medial surface, by a deep groove, the **mastoid notch** (digastric fossa), for the origin of the *digastric* muscle, and again medially by the **occipital groove** for the occipital artery.

The outer surface is perforated by numerous foramina, one, of large size, being usually situated near the posterior border and called the **mastoid foramen.** It transmits a vein to the transverse (lateral) sinus and the mastoid branch of the occipital artery. The mastoid portion gives attachment externally to the *auricularis posterior* (*retrahens aurem*) and *occipitalis*, and, along with the mastoid process, to the *sterno-mastoid, splenius capitis*, and *longissimus capitis* (*trachelo-mastoid*). Projecting from the postero-superior margin of the external auditory meatus there is frequently a small tubercle—the **supra-meatal spine**—behind which the surface is depressed to form the **mastoid (supra-meatal) fossa.**

The inner surface of the mastoid portion presents a deep curved **sigmoid groove,** in which is lodged a part of the transverse sinus; the **mastoid foramen** is seen opening into the groove. The interior of the mastoid portion, in the adult, is usually occupied by cavities lined by mucous membrane and known as the **mastoid air-cells** (fig. 97). These open into a small chamber—the **mastoid antrum**—which communicates with the upper part of the tympanic cavity. The mastoid cells are arranged in three groups: (1) antero-superior, (2) middle, and (3) apical. The apical cells, situated at the apex of the mastoid process, are small and usually contain marrow.

Borders.—The superior border is broad and rough for articulation with the hinder part of the inferior border of the parietal bone. The posterior border, very uneven and serrated, articulates with the inferior border of the occipital bone, extending from the lateral angle to the jugular process.

The **petrous portion** [pars petrosa; pyramis] is a pyramid of very dense bone presenting for examination a base, an apex, three (or four) surfaces, and three (or four) borders or angles. Two sides of the pyramid look into the cranial cavity, the posterior into the posterior cranial fossa, and the anterior into the middle cranial fossa. The inferior surface appears on the under surface of the cranium. The medial and posterior walls of the tympanic cavity in the temporal bone are sometimes described as a fourth side of the pyramid. The base forms a part of the lateral surface of the cranium; the apex is placed medially.

The **posterior surface** of the pyramid is triangular in form, bounded above by the superior angle and below by the posterior angle Near the middle is an obliquely directed foramen [porus acusticus internus] leading into a short canal—the **internal auditory meatus**—at the bottom of which is a plate of bone, pierced by numerous foramina, and known as the **lamina cribrosa.** The canal transmits the facial and auditory nerves, the pars intermedia, and the internal auditory artery. The bottom of the internal auditory meatus can be most advantageously studied in a temporal bone at about the time of birth, when the canal is shallow and the openings relatively wide.

The fundus of the meatus is divided by a transverse ridge of bone, the ***transverse crest,*** into a superior and inferior fossa. Of these, the superior is the smaller, and presents anteriorly the beginning of the **facial canal** (aqueduct of Fallopius), which transmits the seventh nerve. The rest of the surface above the crest is dotted with small foramina (the superior vestibular area) which transmit nerve-twigs to the recessus ellipticus (fovea hemielliptica) and the ampullæ of the superior and lateral semicircular canals (vestibular division of the auditory nerve). Below the crest there are two depressions and an opening. Of these, an anterior curled tract (the spiral cribriform tract) with a central foramen (foramen centrale cochleare) marks the base of the cochlea; the central foramen indicates the orifice of the canal of the modiolus, and the smaller foramina transmit the cochlear twigs of the auditory nerve. The posterior opening (foramen singulare) is for the nerve to the ampulla of the posterior semicircular canal. The middle depression (inferior vestibular area) is dotted with minute foramina for the nerve-twigs to the saccule, which is lodged in the recessus sphæricus (fovea hemisphærica). The inferior fossa is subdivided by a low vertical crest. The fossa in front of the crest is the *fossula cochlearis*, and the recess behind it is the *fossula vestibularis*.

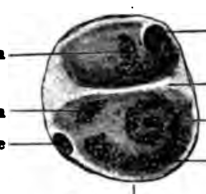
Behind and lateral to the meatus is a narrow fissure, the **aquæductus vestibuli,** covered by a scale of bone. In the fissure lies the ductus endolymphaticus, a small arteriole and venule, and a process of connective tissue which unites the dura mater to the sheath of the internal ear. Occasionally a bristle can be passed through it into the vestibule. Near the upper margin, and opposite a point about midway between the meatus and the aqueduct of the vesti-

bule, is an irregular opening, the **fossa subarcuata**, the remains of the **floccular fossa**, a conspicuous depression in the fœtal bone. In the adult the depression usually lodges a process of dura mater and transmits a small vein, though in some bones it is almost obliterated.

The **anterior surface** of the pyramid, sloping downward and forward, forms the back part of the floor of the middle fossa of the cranium.

Upon the anterior surface of the pyramid will be found the following points of interest, proceeding from the apex toward the base of the pyramid:—(1) a shallow **trigeminal impression** for the semilunar (Gasserian) ganglion of the trigeminal nerve; (2) two small grooves running backward and laterally toward two small foramina overhung by a thin osseous lip, the larger and medial of which, known as the **hiatus canalis facialis**, transmits the great superficial petrosal nerve and the petrosal branch of the middle meningeal artery, whilst the smaller and lateral foramen is for the small superficial petrosal nerve; (3) behind and lateral to these is an eminence—the **eminentia arcuata**—best seen in young bones, corresponding to the superior semicircular canal in the interior; (4) still more laterally is a thin transulcent plate of bone, roofing in the tympanic cavity, and named the tegmen tympani.

FIG. 94.—THE FORAMINA IN THE FUNDUS OF THE LEFT INTERNAL AUDITORY MEATUS OF A CHILD AT BIRTH (‡). (Diagrammatic.)



The **inferior** or **basilar surface** of the pyramid is very irregular. At the apex it is rough, quadrilateral, and gives attachment to the *tensor tympani, levator veli palatini,* and the pharyngeal aponeurosis. Behind this are seen the large circular orifice of the **carotid canal** for the transmission of the carotid artery and a plexus of sympathetic nerves, and on the same level, near the posterior border, a small three-sided depression, the **canaliculus cochleæ**, which transmits a small vein from the cochlea to the internal jugular. Behind these two openings is the large elliptical **jugular fossa** which forms the anterior and lateral part of the bony wall of the jugular foramen, in which is contained a dilatation on the commencement of the internal jugular vein; on the lateral wall of the jugular fossa is a minute foramen, the **mastoid canaliculus**, for the entrance of the auricular branch of the vagus (Arnold's nerve) into the interior of the bone. Between the inferior aperture of the carotid canal and the jugular fossa is the **sharp carotid ridge**, on which is a small depression, the **fossula petrosa**, and at the bottom of this a minute opening, the **tympanic canaliculus**, for the tympanic branch of the glosso-pharyngeal or Jacobson's nerve, and the small tympanic branch from the ascending pharyngeal artery. Behind the fossa is the rough **jugular surface** for articulation with the jugular process of the occipital bone, on the lateral side of which is the prominent cylindrical spur known as the **styloid process** with the **stylo-mastoid** foramen at its base. The facial nerve, and sometimes the auricular branch of the vagus, leave the skull, and the stylo-mastoid artery enters it by this foramen. Running backward from the foramen are the mastoid and occipital grooves already described.

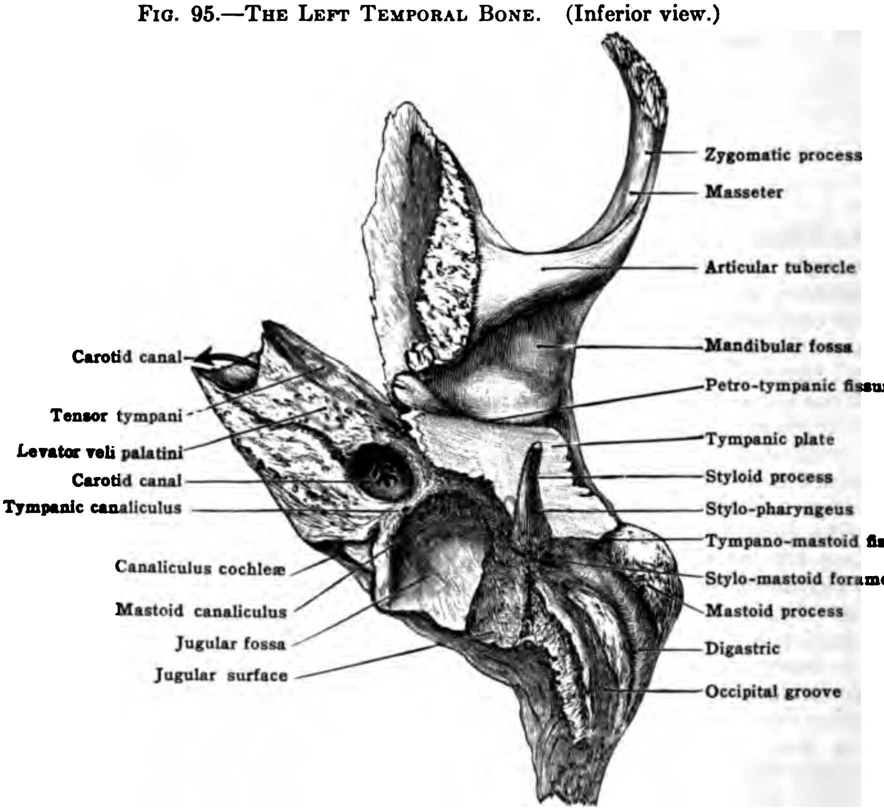
The **tympanic surface** of the pyramid, forming the medial and posterior walls [paries labyrinthica] of the tympanic cavity, is shown by removing the tympanic plate (fig. 91). It presents near the base an excavation, known as the **tympanic** or **mastoid antrum**, covered by the triangular part of the squamous below and behind the temporal line. The opening of the antrum into the tympanic cavity is situated immediately above the **fenestra vestibuli**, an oval-shaped opening which receives the base of the stapes; below the fenestra vestibuli is a convex projection or **promontory**, marked by grooves for the tympanic plexus of nerves and containing the commencement of the first turn of the cochlea. In the lower and posterior part of the promontory is the **fenestra cochleæ**, closed in the recent state by the **secondary** membrane of the tympanum. Running downward and forward from the front of the fenestra vestibuli is a thin curved plate of bone [**septum canalis musculotubarii**], separating two grooves converted

into canals by the overlying tympanic plate. The lower is the groove for the **Eustachian tube** [semicanalis tubæ auditivæ], the communicating passage between the tympanum and the pharynx; the upper is the **semicanalis m. tensoris tympani,** and the lateral apertures of both canals are visible in the retiring angle, between the petrous and squamous portions of the bone.

The **apex** of the pyramid is truncated and presents the medial opening of the carotid canal. The latter commences on the inferior surface, and, after ascending for a short distance, turns forward and medially, tunnelling the bone as far as the apex, and finally opens into the upper part of the **foramen lacerum** formed between the temporal and sphenoid bones. One or two minute openings in the wall of the carotid canal, known as the **carotico-tympanic canaliculi,** transmit communicating twigs between the carotid and tympanic plexuses. The upper part of the apex is joined by cartilage to the posterior petrosal process of the sphenoid.

The **base** is the part of the pyramid which appears laterally at the side of the cranium and takes part in the formation of the mastoid portion. It is described with that division of the bone.

FIG. 95.—THE LEFT TEMPORAL BONE. (Inferior view.)



Angles.—The **superior angle** (border) of the pyramid is the longest and separates the posterior from the anterior surface. It is grooved for the superior petrosal sinus, gives attachment to the tentorium cerebelli, and presents near the apex a semilunar notch upon which the fifth cranial nerve lies. Near its medial end there is often a small projection for the attachment of the petro-sphenoidal ligament, which arches over the inferior petrosal sinus and the sixth nerve. The **posterior angle** separates the posterior from the inferior surface, and when articulated with the occipital, forms the groove for the inferior petrosal sinus, and completes the **jugular foramen** formed by the temporal in front and on the lateral side, and by the occipital behind and on the medial side. The jugular foramen is divisible into three compartments: an anterior for the inferior petrosal sinus, a middle for the glossopharyngeal, vagus and accessory cranial nerves, and a posterior for the internal jugular vein and some meningeal branches from the occipital and ascending pharyngeal arteries. The **anterior angle** is the shortest and consists of two parts, one joined to the squamous in the petro-squamous suture and a small free part internally which articulates with the sphenoid. A fourth or inferior border may be distinguished, which runs along the line of junction with the tympanic plate and is continued on to the rough area below the apex.

The **tympanic portion** [pars tympanica] is quadrilateral in form, hollowed out above and behind, and nearly flat, or somewhat concave, in front and below. It forms the whole of the anterior and inferior walls, and part of the posterior wall, of the external auditory meatus, and is separated behind from the mastoid process by the **tympano-mastoid** (auricular) fissure through which the auricular branch of the vagus in some cases leaves the bone.

In front it is separated by the **petro-tympanic** fissure from the squamous portion. Through the petro-tympanic fissure the tympanic branch of the internal maxillary artery and the so-called laxator tympani pass. The processus gracilis of the malleus is lodged within it, and a narrow subdivision at its inner end, known as the **canal of Huguier**, transmits the chorda tympani nerve. The tympanic part presents for examination two surfaces and four borders.

The **antero-inferior surface**, directed downward and forward, lodges part of the parotid gland. Near the middle it is usually very thin, and sometimes presents a small foramen (the foramen of Huschke), which represents a non-ossified portion of the plate. The **postero-superior surface** looks into the external auditory meatus and tympanic cavity, and at its medial end is a narrow groove, the **sulcus tympanicus**, deficient above, which receives the membrana tympani.

The **lateral border** is rough and everted, forming the **external auditory process** for the attachment of the cartilage of the pinna; the **superior border** enters into the formation of the petro-tympanic fissure; the **inferior border** is uneven and prolonged into the **vaginal process** [vagina processus styloidei] which surrounds the lateral aspect of the base of the styloid process and gives attachment to the front part of the fascial sheath of the carotid vessels; the **medial border**, short and irregular, lies immediately below and to the lateral side of the opening of the Eustachian tube, and becomes continuous with the rough quadrilateral area on the inferior aspect of the apex.

The **external auditory meatus** is formed partly by the tympanic and partly by the squamous portion. It is an elliptical bony tube leading into the tympanum, the extrance of which is bounded throughout the greater part of its circumference by the external auditory process of the tympanic plate. Above, the entrance is limited by the temporal ridge or posterior root of the zygomatic process.

The **styloid process** is a slender, cylindrical spur of bone fused with the inferior aspect of the temporal immediately in front of the stylo-mastoid foramen. It consists of two parts, **basal** (tympano-hyal), which in the adult lies under cover of the tympanic plate, and a **projecting** portion (stylo-hyal), which varies in length from five to fifty millimetres. When short, it is hidden by the vaginal process, but, on the other hand, it may reach to the hyoid bone. The projecting portion gives attachment to three muscles and two ligaments.

The *stylo-pharyngeus* arises near the base from the medial and slightly from the posterior aspect; the *stylo-hyoid* from the posterior and lateral aspect near the middle; and the *stylo-glossus* from the front near the tip. The tip is continuous with the stylo-hyoid ligament, which runs down to the lesser cornu of the hyoid bone. A band of fibrous tissue—the stylo-mandibular ligament—passes from the process below the origin of the stylo-glossus to the angle of the lower jaw.

Blood-supply.—The arteries supplying the temporal bone are derived from various sources. The chief are:—

Stylo-mastoid from posterior auricular: it enters the stylo-mastoid foramen.

Anterior tympanic from internal maxillary: it passes through the petro-tympanic fissure.

Superficial petrosal from middle meningeal: transmitted by the hiatus canalis facialis.

Carotico-tympanic from internal carotid whilst in the carotid canal.

Internal auditory from the basilar: it enters the internal auditory meatus, and is distributed to the cochlea and vestibule.

Other less important twigs are furnished by the middle meningeal, the meningeal branches of the occipital, and by the ascending pharyngeal artery. The squamous portion is supplied, on its internal surface, by the middle meningeal, and externally by the branches of the deep temporal from the internal maxillary.

Articulations.—The temporal bone articulates with the occipital, parietal, sphenoid, zygomatic, and, by a movable joint, with the mandible. Occasionally the squamous portion presents a process which articulates with the frontal. A **fronto-squamosal** suture is common in the skulls of the lower races of men, and is normal in the skulls of the chimpanzee, gorilla, and gibbon.

Ossification.—Of the three parts which constitute the temporal bone at birth, the squamosal and tympanic develop in membrane and the petrosal in cartilage. The squamosal is formed from one centre, which appears as early as the eighth week, and ossification extends into the zygomatic process, which grows concurrently with the squamosal. At first the tympanic border is nearly straight, but soon assumes its characteristic horseshoe shape. At birth the post-glenoid tubercle is conspicuous, and at the hinder end of the squamosal there is a process which comes into relation with the mastoid antrum The centre for the tympanic element appears about the twelfth week. At birth it forms an incomplete ring, open above, and slightly ankylosed to the lower border of the squamosal. The anterior extremity terminates

in a small irregular process, and the medial aspect presents, in the lower half of its circumference, a groove for the reception of the tympanic membrane.

Up to the middle of the fifth month the periotic capsule is cartilaginous; it then ossifies so rapidly that by the end of the sixth month its chief portion is converted into porous bone. The ossific material is deposited in four centres, or groups of centres, named according to their relation to the ear-capsule in its embryonic position.

The nuclei are deposited in the following order:—

1. The **opisthotic** appears at the end of the fifth month. The osseous material is seen first on the promontory, and it quickly surrounds the fenestra cochleæ from above downward, and forms the floor of the vestibule, the lower part of the fenestra vestibuli, and the internal auditory meatus; it also invests the cochlea. Subsequently a plate of bone arises from it to surround the internal carotid artery and form the floor of the tympanum.

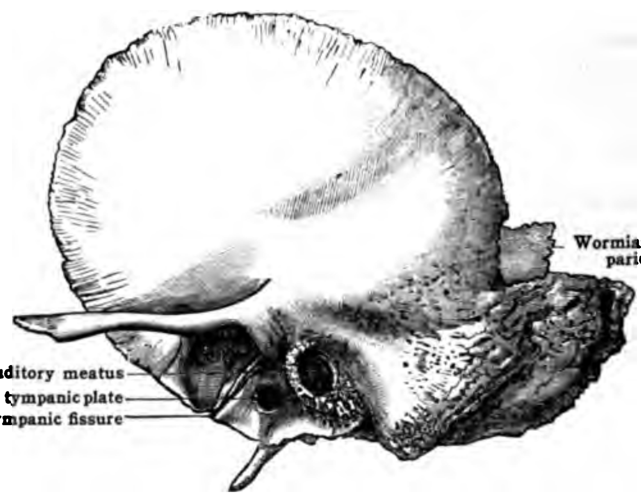
2. The **prootic** nucleus is deposited behind the internal auditory meatus near the medial limb of the superior semicircular canal. It covers in a part of the cochlea, the vestibule, and the internal auditory meatus, completes the fenestra vestibuli, and invests the superior semicircular canal.

3. The **pterotic** nucleus ossifies the tegmen tympani and covers in the lateral semicircular canal; the ossific matter is first deposited over the lateral limb of this canal.

4. The **epiotic**, often double, is the last to appear, and is first seen at the most posterior part of the posterior semicircular canal.

At birth the bone is of loose and open texture, thus offering a striking contrast to the dense and ivory-like petrosal of the adult. It also differs from the adult bone in several other particulars. The floccular fossa is widely open and conspicuous. Voltolini has pointed out that a small canal leads from the floor of the floccular fossa and opens posteriorly on the mastoid surface of the bone; it may open in the mastoid antrum. The hiatus canalis facialis is unclosed

FIG. 96.—TEMPORAL BONE AT THE SIXTH YEAR.



and the tympanum is filled with gelatinous connective tissue. The mastoid process is not developed, and the jugular fossa is a shallow depression.

After birth the parts grow rapidly. The tympanum becomes permeated with air, the various elements fuse, and the tympanic annulus grows rapidly and forms the tympanic plate. Development of the tympanic plate takes place by an outgrowth of bone from the lateral aspect of the tympanic annulus. This outgrowth takes place most rapidly from the tubercles or spines at its upper extremities, and in consequence of the slow growth of the lower segment a deep notch is formed; gradually the tubercles coalesce, lateral to the notch, so as to enclose a foramen which persists until puberty, and sometimes even in the adult. In most skulls a cleft capable of receiving the nail remains between the tympanic element and the mastoid process; this is the tympano-mastoid fissure. The anterior portion of the tympanic plate forms with the inferior border of the squamosal a cleft known as the petro-tympanic fissure, which is subsequently encroached upon by the growth of the petrosal. As the tympanic plate increases in size it joins the lateral wall of the carotid canal and presents a prominent lower edge, known as the vaginal process (sheath of the styloid).

The **mastoid process** becomes distinct about the first year, coincident with the obliteration of the petro-squamous suture, and increases in thickness by deposit from the periosteum. According to most writers, the process becomes pneumatic about the time of puberty, but it has been shown by Young and Milligan that the mastoid air-cells develop at a much earlier period than is usually supposed. These writers have described specimens in which the air-cells were present, as small pit-like diverticula from the mastoid antrum, in a nine months' fœtus and in an infant one year old. In old skulls the air-cells may extend into the jugular process of the occipital bone.

At birth the mastoid antrum is relatively large and bounded laterally by a thin plate of bone belonging to the squamosal (post-auditory process). As the mastoid increases in thickness the antrum comes to lie at a greater depth from the surface and becomes relatively smaller.

The styloid process is ossified in cartilage from two centres, one of which appears at the base in the tympano-hyal before birth. This soon joins with the temporal bone, and in the second year a centre appears for the stylo-hyal, which, however, remains very small until puberty. In the adult it usually becomes firmly united with the tympano-hyal, but it may remain permanently separate.

THE TYMPANUM

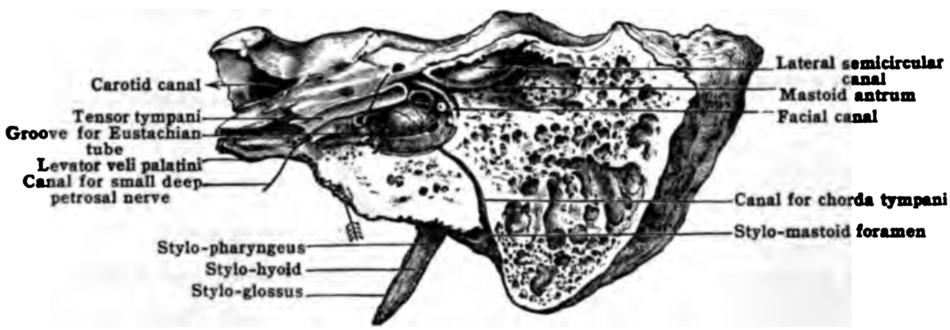
The **tympanum** (middle ear) includes a cavity [cavum tympani] of irregular form in the temporal bone, situated over the jugular fossa, between the petrous portion medially and the tympanic and squamous portions laterally. When fully developed, it is completely surrounded by bone except where it communicates with the external auditory meatus, and presents for examination six walls—lateral, medial, posterior, anterior, superior (roof), and inferior (floor). The lateral and medial walls are flat, but the remainder are curved, so that they run into adjoining surfaces, without their limits being sharply indicated.

The **roof** or tegmen tympani [paries tegmentalis] is a translucent plate of bone, forming part of the superior surface of the petrous portion and separating the tympanum from the middle fossa of the skull. The **floor** [paries jugularis] is the plate of bone which forms the roof of the jugular fossa.

The **medial wall** [paries labyrinthica] is formed by the tympanic surface of the petrous portion. In the angle between it and the roof is a horizontal ridge which extends backward as far as the posterior wall and then turns downward in the angle between the medial and posterior walls. This is the **facial (Fallopian) canal,** and is occupied by the facial nerve. The other features of this surface—viz., the **fenestra vestibuli,** the **fenestra cochleæ,** and the **promontory**—have previously been described with the anterior surface of the petrous portion of the temporal bone.

The **posterior wall** [paries mastoidea] of the tympanum is also formed by the anterior surface of the petrous portion. At the superior and lateral angle of this wall an opening

FIG. 97.—THE MEDIAL WALL OF THE TYMPANUM.



leads into the **mastoid antrum.** Immediately below this opening there is a small hollow cone, the **pyramidal eminence,** the cavity of which is continuous with the descending limb of the facial canal. The cavity is occupied by the *stapedius* and the tendon of the muscle emerges at the apex. One or more bony spicules often connect the apex of the pyramid with the promontory.

The roof and floor converge toward the **anterior extremity** of the tympanum, which is, in consequence, very low; it is occupied by two semicanals, the lower for the Eustachian tube, the upper for the *tensor tympani* muscle. These channels are sometimes described together as the **canalis musculo-tubarius.** In carefully prepared bones the upper semicanal is a small horizontal hollow cone (anterior pyramid), 12 mm. in length; the apex is just in front of the fenestra vestibuli, and is perforated to permit the passage of the tendon of the muscle. As a rule, the thin walls of the canal are damaged, and represented merely by a thin ridge of bone. The posterior portion of this ridge projects into the tympanum, and is known as the **processus cochleariformis.** The thin septum between the semicanal for the tensor tympani and the tube is pierced by a minute opening which transmits the small deep petrosal nerve.

The **lateral wall** [paries membranacea] is occupied mainly by the external auditory meatus. This opening is closed in the recent state by the tympanic membrane. The rim of bone to which the membrane is attached is incomplete above, and the defect is known as the **tympanic notch (notch of Rivinus).** Anterior to this notch, in the angle between the squamous portion and the tympanic plate, is the **petro-tympanic (Glaserian) fissure,** and the small passage which transmits the chorda tympani nerve, known as the **canal of Huguier.**

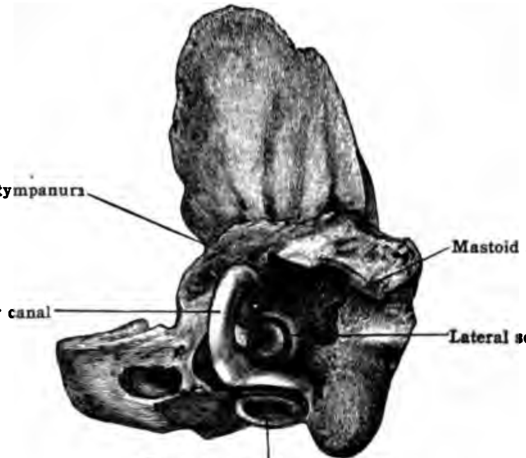
Up to this point the description of the middle ear conforms to that in general usage. But Young and Milligan have laid stress on the fact that the middle ear is really a cleft, named by them the "*middle-ear cleft,*" which intervenes between the periotic capsule, on the one hand, and the squamo-zygomatic and tympanic elements of the temporal bone on the other. This cleft, as development proceeds, gives rise to three cavities:—(1) the mastoid antrum; (2)

tympanum; and (3) the Eustachian tube. They point out that "the cleft is primarily continuous, and however much it may be altered in shape and modified in parts to form these three cavities, that continuity is never lost." It will be clear that the mastoid antrum, according to this view, is not an outgrowth from the tympanum, but is simply the lateral end of the middle-ear cleft.

The tympanic cavity may be divided into three parts. The part below the level of the superior margin of the external auditory meatus is the **tympanum proper**; the portion above this level is the **epitympanic recess** or **attic**; it receives the head of the malleus, the body of the incus, and leads posteriorly into the recess known as the **mastoid antrum.** The third part is the downward extension known as the **hypotympanic recess.**

The tympanic or mastoid antrum.—The air-cells which in the adult are found in the interior of the mastoid portion of the temporal bone open into a small cavity termed the **mastoid antrum.** This is an air-chamber, communicating with the attic of the tympanum, and separated from the middle cranial fossa by the posterior portion of the tegmen tympani. The floor is formed by the mastoid portion of the petrosal, and the lateral wall by the squamosal, below the temporal ridge. In children the outer wall is exceedingly thin, but in the adult it is of considerable thickness. The lateral semicircular canal projects into the antrum on its

FIG. 98.—TEMPORAL BONE AT BIRTH DISSECTED FROM ABOVE AND BEHIND TO SHOW THE SEMICIRCULAR CANALS AND THE MASTOID ANTRUM. (Enlarged $\frac{1}{2}$.)



medial wall, and is very conspicuous in the fœtus. Immediately below and in front of the canal is the facial nerve, contained in the facial canal.

The mastoid antrum has somewhat the form of the bulb of a retort (Thane and Godlee) compressed laterally, and opening by its narrowed neck into the attic or epitympanic recess. Its dimensions vary at different periods of life. It is well developed at birth, attains its maximum size about the third year, and diminishes somewhat up to adult life. In the adult the plate of bone which forms the lateral wall of the antrum is 12 to 18 mm. ($\frac{1}{2}$ to $\frac{3}{4}$ in.) in thickness, whereas at birth it is about 1.8 mm. ($\frac{1}{16}$ in.) or less. The deposition of bone laterally occurs, therefore, at average rate of nearly 1 mm. a year in thickness. In the adult the antrum is about 12 mm. ($\frac{1}{2}$ in.) from front to back, 9 mm. ($\frac{3}{8}$ in.) from above downward, and 4.5 mm. ($\frac{3}{16}$ in.) from side to side.

A canal occasionally leads from the mastoid antrum through the petrous bone to open in the recess which indicates the position of the floccular fossa; it is termed the petro-mastoid canal. (Gruber.)

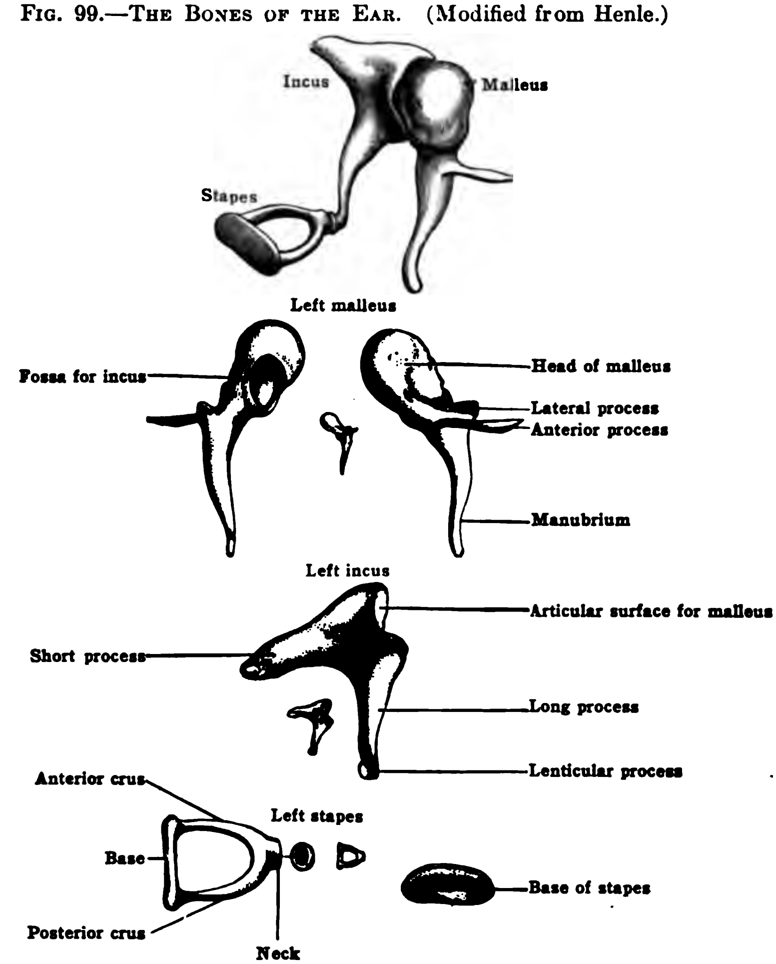
The facial (Fallopian) canal.—This canal begins at the anterior angle of the superior fossa of the internal auditory meatus, and passes forward and laterally above the vestibular portion of the internal ear for a distance of 1.5–2.0 mm. At the lateral end of this portion of its course it becomes dilated to accommodate the geniculate ganglion, and then turns abruptly backward and runs in a horizontal ridge on the medial wall of the tympanum, lying in the angle between it and the tegmen tympani, immediately above the fenestra vestibuli, and extending as far backward as the entrance to the mastoid antrum. Here it comes into contact with the inferior aspect of the projection formed by the lateral semicircular canal, and then turns vertically downward, running in the angle between the medial and posterior walls of the tympanum to terminate at the stylo-mastoid foramen.

The canal is traversed by the facial nerve. Numerous openings exist in the walls of this passage. At its abrupt bend, or genu, the greater and smaller superficial petrosal nerves escape from, and a branch from the middle meningeal artery enters, the canal, and in the vertical part of its course the cavity of the pyramid opens into it. There is also a small orifice by which the auricular branch of the vagus joins the facial, and near its termination the **iter chordæ posterius** for the chorda tympani nerve leads from it into the tympanum.

The small bones of the tympanum.—These bones, the malleus, incus and stapes, are contained in the upper part of the tympanic cavity. Together they form a jointed column of bone connecting the membrana tympani with the fenestra vestibuli.

The malleus.—This is the most external of the auditory ossicles, and lies in relation with the tympanic membrane. Its upper portion, or **head,** is lodged in the epitympanic recess. It is of rounded shape, and presents posteriorly an elliptical depression for articulation with the incus. Below the head is a constricted portion or **neck,** from which three processes diverge. The largest is the **handle** or **manubrium,** which is slightly twisted and flattened. It forms an obtuse angle with the head of the bone, and lies between the membrana tympani and the mucous membrane covering its inner surface. The *tensor tympani* tendon is inserted into the manubrium near its junction with the neck on the medial side.

FIG. 99.—THE BONES OF THE EAR. (Modified from Henle.)



The **anterior process** (processus gracilis or Folii) is a long, slender, delicate spiculum of bone (rarely seen of full length except in the fœtus), projecting nearly at right angles to the anterior aspect of the neck, and extending obliquely downward. It lies in the petro-tympanic fissure, and in the adult usually becomes converted into connective tissue, except a small basal stump. The **lateral process** is a conical projection from the lateral aspect of the base of the manubrium. Its apex is connected to the upper part of the tympanic membrane, and its base receives the lateral ligament of the malleus. The malleus also gives attachment to a superior ligament and an anterior ligament, the latter of which was formerly described as the *laxator tympani* muscle.

The incus.—This bone is situated between the malleus externally and the stapes internally. It presents for examination a body and two processes. The **body** is deeply excavated anteriorly for the reception of the head of the malleus. The **short process** projects backward, and is connected by means of ligamentous fibres to the posterior wall of the tympanum, near the entrance to the mastoid antrum. The **long process** is slender, and directed downward and inward, and lies parallel with the manubrium of the malleus. On the medial aspect of the distal extremity of this process is the **lenticular process** (orbicular tubercle), separate in early life, but

subsequently joined to the process by a narrow neck. Its free surface articulates with the head of the stapes.

The **stapes** is the innermost ossicle. It has a **head** directed horizontally outward, capped at its outer extremity by a disc resembling the head of the radius. The cup-shaped depression receives the lenticular process of the incus. The **base** occupies the fenestra vestibuli, and like this opening, the inferior border is straight, and the superior curved. The base is connected with the head by means of two **crura**, and a narrow piece of bone called the neck. Of the two crura, the anterior is the shorter and straighter. The crura with the base form a stirrup-shaped arch, of which the inner margin presents a groove for the reception of the membrane stretched across the hollow of the stapes. In the early embryo this hollow is traversed by the stapedial artery. The **neck** is very short, and receives on its posterior border the tendon of the *stapedius* muscle.

Development.—The tympanic cavity represents the upper extremity of the first endodermal branchial groove, which becomes converted into a blind pouch, the communication of which with the pharyngeal cavity is the tuba auditiva (Eustachian tube). The thin membrane which separates the endodermal from the ectodermal groove becomes the tympanic membrane, and it is from the upper extremities of the axial skeletons of the first and second branchial arches, which bound the groove anteriorly and posteriorly, that the auditory ossicles are formed, the malleus and incus belonging to the first arch and the stapes to the second (Reichert). The ossicles consequently lie originally in the walls of the cavity, but they are surrounded by a loose spongy tissue, which, on the entrance of air into the cavity, becomes compressed, allowing the cavity to enfold the ossicles. These therefore are enclosed within an epithelium which is continuous medially with that lining the posterior tympanic wall, and laterally with that lining the internal surface of the tympanic membrane.

The mastoid cells are outgrowths of the cavity into the adjacent bone, and are therefore lined with an epithelium continuous with that of the cavity.

THE OSSEOUS LABYRINTH

The **osseous labyrinth** [labyrinthus osseus] (fig. 100) is a complex cavity hollowed out of the petrous portion of the temporal bone and containing the membranous labyrinth, the essential part of the organ of hearing. It is incompletely divided into three parts, named the vestibule, the semicircular canals, and the cochlea.

FIG. 100.—THE LEFT OSSEOUS LABYRINTH. (After Henle. From a cast.)

The vestibule.—This is an oval chamber situated between the base of the internal auditory meatus and the medial wall of the tympanum, with which it communicates by way of the fenestra vestibuli. Anteriorly, the vestibule leads into the cochlea, and posteriorly it receives the extremities of the semicircular canals. It measures about 3 mm. transversely, and is somewhat longer antero-posteriorly.

Its medial wall presents at the anterior part a circular depression, the **spherical recess** (fovea hemispherica), which is perforated for the passage of nerve-twigs. This recess is separated by a vertical ridge (the **crista vestibuli**) from the vestibular orifice of the **aquæductus**

FIG. 101.—THE COCHLEA IN SAGITTAL SECTION. (After Henle.)

vestibuli, which passes obliquely backward to open on the posterior surface of the petrosal. The roof contains an oval depression—the **elliptical recess** (fovea hemielliptica).

The **semicircular canals** are three in number. Arranged in different planes, each forms about two-thirds of a circle. One extremity of each canal is dilated to form an **ampulla**.

The **superior canal** lies transversely to the long axis of the petrosal, and is nearly vertical;

its highest limb makes a projection on the superior surface of the bone. The ampulla is at the lateral end; the medial end opens into the vestibule conjointly with the superior limb of the posterior canal.

The **posterior canal** is nearly vertical and lies in a plane nearly parallel to the posterior surface of the petrosal. It is the longest of the three; its upper extremity joins the medial limb of the superior canal, and opens in common with it into the vestibule. The lower is the ampullated end.

The **lateral canal** is placed horizontally and arches laterally; its lateral limb forms a prominence in the mastoid antrum. This canal is the shortest; its ampulla is at the lateral end near the fenestra vestibuli.

The cochlea.—This is a cone-shaped cavity lying with its base upon the internal auditory meatus, and the apex directed forward and laterally. It measures about five millimetres in length, and the diameter of its base is about the same. The centre of this cavity is occupied by a column of bone—the **modiolus**—around which a canal is wound in a spiral manner, making about two and a half turns. This is the **spiral canal** of the cochlea; its first turn is the largest and forms a bulging, the **promontory**, on the medial wall of the tympanum.

Projecting into the canal throughout its entire length there is a horizontal, shelf-like lamella, the **lamina spiralis**, which terminates at the apex of the cochlea in a hook-like process, the **hamulus**. The free edge of the lamina spiralis gives attachment to the membranous cochlea, a canal having in section the form of a triangle whose base is attached to the lateral wall of the spiral canal. By this the spiral canal is divided into a portion above the lamina spiralis, termed the **scala vestibuli**, which communicates at its lower end with the osseous vestibule, and a portion below, termed the **scala tympani**, which abuts at its lower end upon the fenestra cochleæ. The two scalæ communicate at the apex of the cochlea by the **helicotrema**. Near the commencement of the scala tympani, and close to the fenestra rotunda, is the cochlear orifice of the **canaliculus cochleæ** (ductus perilymphaticus). In the adult this opens below, near the middle of the posterior border of the petrous bone, and transmits a small vein from the cochlea to the jugular fossa.

Measurements of the principal parts connected with the auditory organs:—

Internal auditory meatus.......	Length of anterior wall, 13–14 mm.
	Length of posterior wall, 6.7 mm.
External auditory meatus......	14–16 mm. (Gruber.)
Tympanum..................	Length, 13 mm.
	Height in centre of cavity, 15 mm.
	Width opposite the membrana tympani, 2 mm.
	Width opposite the tubal orifice, 3–4 mm. (Von Tröltsch.)

The capsule of the osseous labyrinth is in length 22 mm. (Schwalbe.)
Superior semicircular canal measures along its convexity 20 mm.
The posterior semicircular canal measures along its convexity 22 mm.
The lateral semicircular canal measures along its convexity 15 mm.
The canal is in diameter 1.5 mm. (Huschke.)
The ampulla of the canal, 2.5 mm.

Development.—The membranous internal ear arises in the embryo as a depression of the ectoderm of the surface of the head opposite the fifth neuromere of the hind-brain and later becomes a sac-like cavity, the otocyst, which separates from its original ectodermal connections and sinks deeply into the subjacent mesoderm, a part of which becomes incorporated with it. The rest of the mesodermal tissue which surrounds the otocyst becomes later the petrous portion of the temporal bone, the perilymph and the internal periosteal layer; the osseous labyrinth is therefore merely the portions of the petrous which enclose the cavity occupied by the membranous internal ear.

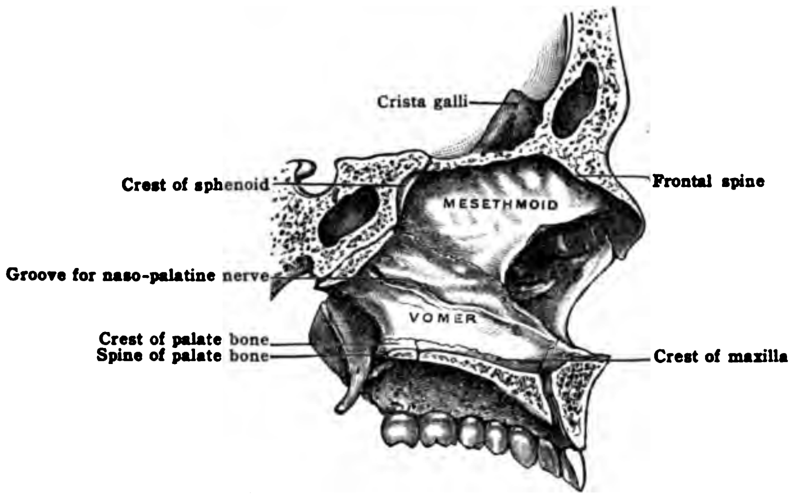
THE ETHMOID

The **ethmoid** [os ethmoidale] is a bone of delicate texture, situated at the anterior part of the base of the cranium (figs. 102, 103, 104). Projecting downward from between the orbital plates of the frontal, it enters into the formation of the orbital and nasal fossæ. It is cubical in form, and its extreme lightness and delicacy are due to an arrangement of very thin plates of bone surrounding irregular spaces known as air-cells. The ethmoid consists of four parts: the horizontal or cribriform plate, the ethmoidal labyrinth on each side, and a perpendicular plate.

The **cribriform plate** [lamina cribrosa] forms part of the anterior cranial fossa, and is received into the ethmoidal notch of the frontal bone. It presents on its upper surface, in the median line, the intra-cranial portion of the perpendicular plate, known as the **crista galli**, a thick, vertical, triangular process with the highest point in front, and a sloping border behind which gives attachment to the falx cerebri. The anterior border is short and in its lower part broadens out to form two **alar processes** which articulate with the frontal bone and complete the **foramen cæcum.** The crista galli is continuous behind with a median ridge, and on each side of the middle line is a groove which lodges the olfactory bulb.

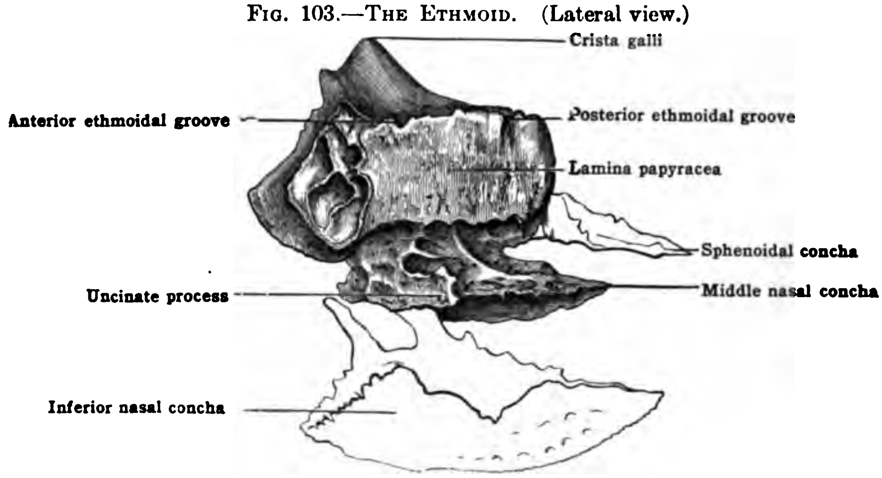
The cribriform plate is pierced, on each side, by numerous foramina, arranged in two or three rows, which transmit the filaments of the olfactory nerves descending from the bulb. Those in the middle of the groove are few and are simple perforations, through which pass the nerves to the roof of the nose; the medial and lateral series are more numerous and constitute the upper ends of small canals, which subdivide as they course downward to the upper parts of the septum and the lateral wall of the nasal fossa. At the front part of the cribriform plate is a narrow longitudinal slit, on each side of the crista galli, which transmits the anterior ethmoidal (nasal) branch of the ophthalmic division of the fifth nerve. The posterior border articulates with the ethmoidal spine of the sphenoid.

FIG. 102.—SECTION THROUGH THE NASAL FOSSA TO SHOW THE MESETHMOID (LAMINA PERPENDICULARIS).



The **perpendicular plate** (mesethmoid) [lamina perpendicularis is directly continuous with the crista galli on the under aspect of the cribriform plate, so that the two plates cross each other at right angles. The larger part of the perpendicular plate is below the point of intersection and forms the upper third of the septum of the nose. It is quadrangular in form with unequal sides.

FIG. 103.—THE ETHMOID. (Lateral view.)



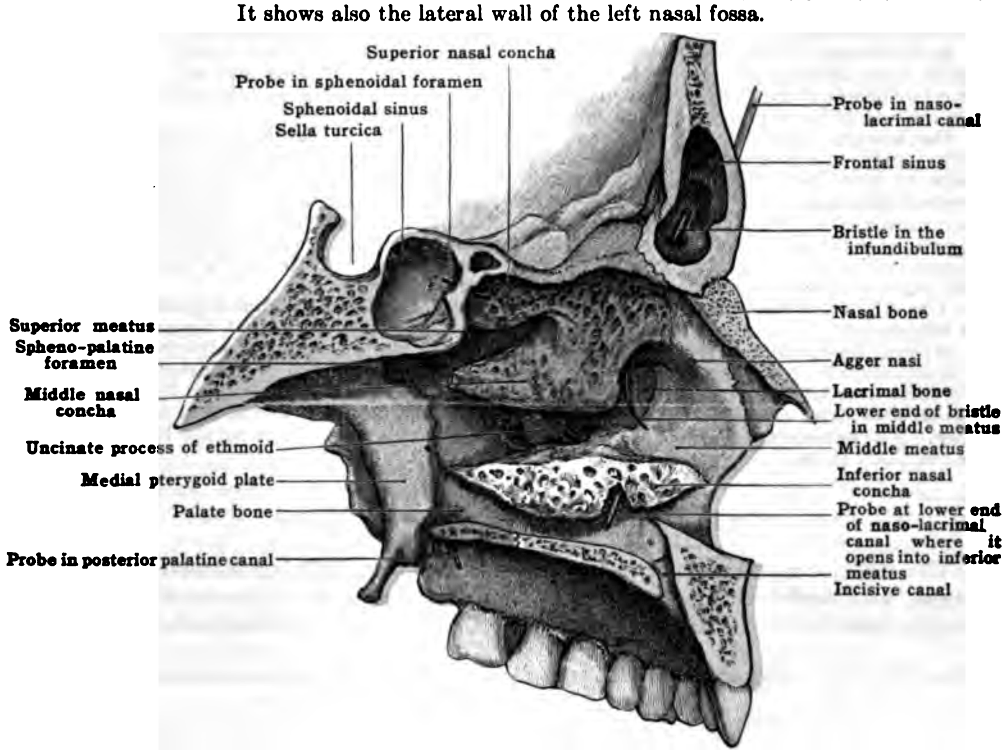
The anterior border articulates with the spine of the frontal and the crest of the nasal bones. The inferior border articulates in front with the septal cartilage of the nose and behind with the anterior margin of the vomer. The posterior margin is very thin and articulates with the crest of the sphenoid. This plate, which is generally deflected a little to one side, presents above a number of grooves and minute canals which lead from the inner set of foramina in the cribriform plate and transmit the olfactory nerves to the septum.

The **labyrinth** (lateral mass) is oblong in shape and suspended from the under aspect of the lateral part of the cribriform plate. It consists of two scroll-like

pieces of bone, the **superior** and **middle nasal conchæ** (turbinate bones), and encloses numerous irregularly shaped spaces, known as the **ethmoidal cells.** These are arranged in three sets—anterior, middle, and posterior ethmoidal cells—and, in the recent state, are lined with prolongations of the nasal mucous membrane. Laterally the labyrinth presents a thin, smooth, quadrilateral plate of bone—the **lamina papyracea** (os planum)—which closes in the middle and posterior ethmoidal cells and forms a large part of the medial wall of the orbit.

By its anterior border it articulates with the lacrimal, and by its posterior border with the sphenoid; the inferior border articulates with the medial margin of the orbital plate of the maxilla and the orbital process of the palate bone, whilst the superior border articulates with the horizontal plate of the frontal. Two notches in the superior border lead into grooves running horizontally across the lateral mass to the cribriform plate, which complete, with the frontal bone, the **ethmoidal canals.** The anterior canal transmits the anterior ethmoidal vessels and (nasal) nerve; the posterior transmits the posterior ethmoidal vessels and nerve.

Fig. 104.—Section through the Nasal Fossa to show the Labyrinth of the Ethmoid. It shows also the lateral wall of the left nasal fossa.



At the lower part of the lateral surface is a deep groove, which belongs to the middle meatus of the nose, and is bounded below by the thick curved margin of the inferior nasal concha. Anteriorly the middle meatus receives the **infundibulum,** a sinuous passage which descends from the frontal sinus through the anterior part of the labyrinth. The anterior ethmoidal cells open into the lower part of the infundibulum, and in this way communicate with the nose, whereas the middle ethmoidal cells open directly into the middle or horizontal part of the meatus. In front of the lamina papyracea are seen a few broken cells, which extend under, and are completed by, the lacrimal bone and the frontal process of the maxilla; from this part of the labyrinth an irregular lamina, known as the **uncinate process,** projects downward and backward. The uncinate process articulates with the ethmoidal process of the inferior nasal concha and forms a small part of the medial wall of the maxillary sinus.

Medially the labyrinth takes part in the formation of the lateral wall of the nasal fossa, and presents the **superior** and **middle nasal conchæ** (turbinate processes), continuous anteriorly, but separated behind by a space directed forward from the posterior margin. This channel is the **superior meatus** of the nose **and communicates** with the posterior ethmoidal cells. The conchæ are covered

in the recent state with mucous membrane and present numerous foramina for blood-vessels and, above, grooves for twigs of the olfactory nerves. Each concha has an attached upper border and a free, slightly convoluted, lower border, and in the case of the middle concha, the lower margin has already been noticed on the outer aspect, where it overhangs the middle meatus of the nose. The posterior extremity of the labyrinth articulates with the anterior surface of the body of the sphenoid and is commonly united with the sphenoidal concha.

A rounded prominence on the lateral wall of the middle meatus is known as the **bulla ethmoidalis.** Antero-inferior to the bulla is a large semilunar depression [hiatus semilunaris] which corresponds to the lower aperture of the infundibulum.

Many of the ethmoidal cells are imperfect and are completed by adjacent bones. Those along the superior edge of the lateral mass are the **fronto-ethmoidal**; those at the anterior border, usually two in number, are known as **lacrimo-ethmoidal.** Those along the lower edge of the lamina papyracea are the **maxillo-ethmoidal**; and posteriorly, are the **spheno-ethmoidal,** completed by the sphenoidal concha, and a **palato-ethmoidal** cell. The anterior extremity presents one or two incomplete cells closed by the nasal process of the maxilla.

Blood-supply.—The ethmoid receives its blood-supply from the anterior and posterior ethmoidal arteries and from the spheno-palatine branch of the internal maxillary.

Articulations.—With the frontal, sphenoid, two palate bones, two nasals, vomer, two inferior nasal conchæ, two sphenoidal conchæ, two maxillæ, and two lacrimal bones. The posterior surface of each labyrinth is in relation with the sphenoid on each side of the crest and rostrum, and helps to close in the sphenoidal sinus.

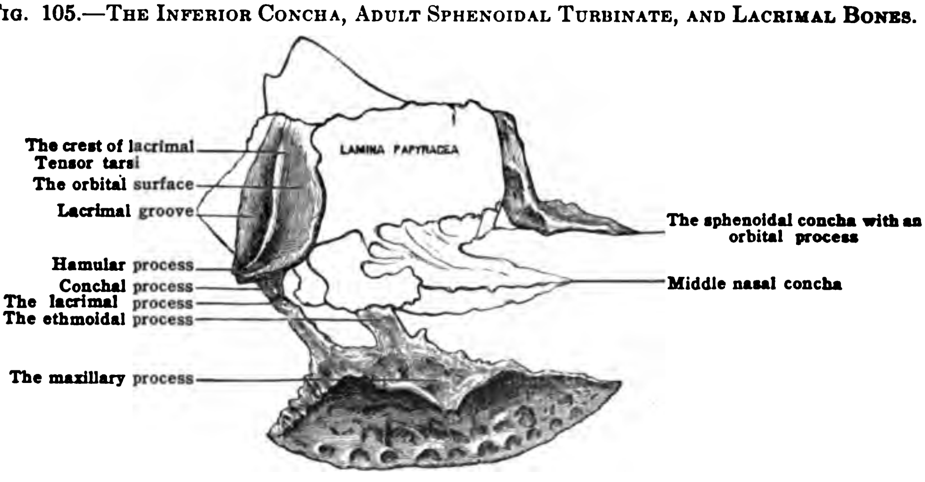
Ossification.—The ethmoid has three centres of ossification. Of these, a nucleus appears in the fourth month of intra-uterine life in each labyrinth, first in the lamina papyracea and afterward extending into the middle concha. At birth each lateral portion is represented by two scroll-like bones, very delicate and covered with irregular depressions, which give it a worm-eaten appearance. Six months after birth a nucleus appears in the ethmo-vomerine cartilage for the vertical plate which gradually extends into the crista galli, and the cribriform plate is formed by ossification extending laterally from this centre, and medially from the labyrinth. The three parts coalesce to form one piece in the fifth or sixth year.

The ethmoidal cells make their appearance about the third year, and gradually invade the labyrinths. In many places there is so much absorption of bone that the cells perforate the ethmoid in situations where it is overlapped by other bones. Along the lower border, near its articulation with the maxilla, the absorption leads to the partial detachment of a narrow strip known as the uncinate process. Sometimes a second but smaller hook-like process is formed, above and anterior to this, so fragile that it is difficult to preserve it in disarticulated bones. The relations of the uncinate process are best studied by removing the lateral wall of the maxillary sinus.

THE INFERIOR NASAL CONCHA

The **inferior nasal concha** (inferior turbinate) (fig. 105) is a slender, scroll-like lamina, attached by its upper margin to the lateral wall of the nasal fossa, and hanging into the cavity in such a way as to separate the middle from the inferior

FIG. 105.—THE INFERIOR CONCHA, ADULT SPHENOIDAL TURBINATE, AND LACRIMAL BONES.



meatus of the nose. It may be regarded as a dismemberment of the ethmoidal labyrinth, with which it is closely related. It presents for examination two surfaces, two borders, and two extremities.

The **lateral surface** is concave, looks toward the lateral wall of the nasal fossa,

and is overhung by the **maxillary process.** The **medial surface** is convex, pitted with depressions, and grooved for vessels, which, for the most part, run longitudinally. The **superior** or **attached border** articulates in front with the conchal crest of the maxilla, then ascends to form the **lacrimal process,** which articulates with the lacrimal bone and forms part of the wall of the lacrimal canal. Behind this, it is turned downward to form the maxillary process, already mentioned, which overhangs the orifice of the maxillary sinus and serves to fix the bone firmly to the lateral wall of the nasal fossa. The projection behind the maxillary process is the **ethmoidal process,** joined in the articulated skull with the uncinate process of the ethmoid across the opening of the maxillary sinus. Posteriorly the upper border articulates with the conchal crest of the palate. The **inferior border** is free, rounded, and somewhat thickened. The **anterior extremity** is blunt and flattened, and broader than the **posterior extremity,** which is elongated, narrow, and pointed.

Articulations.—With the maxilla, lacrimal, palate, and ethmoid.

Ossification.—The inferior nasal concha is ossified in cartilage from a single nucleus which appears in the fifth month of intra-uterine life. At birth it is a relatively large bone and fills up the lower part of the nasal fossa.

THE LACRIMAL

The **lacrimal bone** [os lacrimale] (fig. 105) is extremely thin and delicate, quadrilateral in shape, and situated at the anterior part of the medial wall of the orbit. It is the smallest of the facial bones.

The **orbital surface** is divided by a vertical ridge, the **posterior lacrimal crest,** into two unequal portions. The anterior, smaller portion is deeply grooved to form the **lacrimal groove,** which lodges the lacrimal sac and forms the commencement of the canal for the naso-lacrimal duct. The portion behind the ridge is smooth, and forms part of the medial wall of the orbit. The ridge gives origin to the *orbicularis oculi* (*pars lacrimalis*) muscle and ends below in a hook-like process, the lacrimal hamulus, which curves forward to articulate with the lacrimal tubercle of the maxilla and completes the superior orifice of the naso-lacrimal canal. The **medial surface** is in relation with the two anterior cells of the ethmoid (lacrimo-ethmoidal), forms part of the infundibulum, and inferiorly looks into the middle meatus of the nose. The **superior border** is short, and articulates with the medial angular process of the frontal. The **inferior border** posterior to the crest joins the medial edge of the orbital plate of the maxilla. The narrow piece, anterior to the ridge, is prolonged downward as the **descending process** to join the lacrimal process of the inferior nasal concha. The **anterior border** articulates with the posterior border of the frontal process of the maxilla and the **posterior border** with the lamina papyracea of the ethmoid.

The vessels of the lacrimal bone are derived from the infra-orbital, dorsal nasal branch of the ophthalmic, and anterior ethmoidal arteries.

Articulations.—The lacrimal articulates with the ethmoid, maxilla, frontal, and inferior nasal concha.

Ossification.—This bone arises in the membrane overlying the cartilage of the fronto-nasal plate, and in its mode of ossification is very variable. As a rule, it is formed from a single nucleus which appears in the third or fourth month of intra-uterine life. Not infrequently, the hamulus is a separate element, and occasionally the bone is divided by a horizontal cleft, a process of the lamina papyracea projecting between the two halves to join the frontal process of the maxilla. More rarely the bone is represented by a group of detached ossicles resembling Wormian bones.

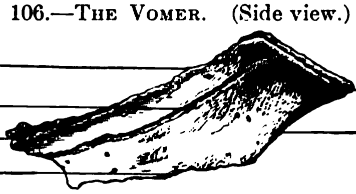
The hamular process is regarded as representing the remains of the facial part of the lacrimal seen in lower animals.

THE VOMER

The **vomer** (fig. 106) (ploughshare bone) is an unpaired flat bone, which lies in the median plane and forms the lower part of the nasal septum. It is thin and irregularly quadrilateral in form, and is usually bent somewhat to one side, though the deflection rarely involves the posterior margin. Each **lateral surface** is covered in the recent state by the mucous membrane of the nasal cavity, and is traversed by a narrow but well-marked groove, which lodges the naso-palatine nerve from the spheno-palatine ganglion.

The **superior border,** by far the thickest part of the bone, is expanded laterally into two **alæ.** The groove between them receives the rostrum of the sphenoid, and the margin of each ala comes into contact with the sphenoidal process of the palate and the vaginal process of the medial pterygoid plate. The **inferior border** is uneven and lies in the groove formed by the crests of the maxillary and palate bones of the two sides. The **anterior border** slopes downward and forward and is grooved below for the septal cartilage of the nose; above it is united with the perpendicular plate of the ethmoid. The **posterior border,** smooth, rounded, and covered by mucus membrane, separates the posterior nares. The **anterior** and inferior borders meet at the anterior extremity of the bone which forms a short vertical ridge behind the incisor crest of the maxillæ. From near the anterior extremity, a small projection passes downward between the incisive foramina.

FIG. 106.—THE VOMER. (Side view.)



Blood-supply.—The arterial supply of the vomer is derived from the anterior and posterior ethmoidal and the spheno-palatine arteries. Branches are also derived from the posterior palatine through the foramen incisivum.

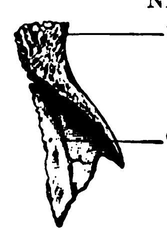
Ossification.—The vomer is ossified from two centres which appear about the eighth week in the membrane investing the ethmo-vomerine cartilage. The two lamellæ unite below during the third month and form a shallow bony trough in which the cartilage lies. In the process of growth the lamellæ extend upward and forward and gradually fuse to form a rectangular plate of bone, the cartilage enclosed between them undergoing absorption at the same time. The alæ on the superior margin and the groove in front are evidence of the original bilaminar condition.

THE NASAL

The **nasal** (figs. 107 and 108) are two small oblong bones situated at the upper part of the face and forming the bridge of the nose. Each bone is thicker and narrower above, thinner and broader below, and presents for examination two surfaces and four borders.

FIG. 107.—THE LEFT NASAL BONE, FACIAL SURFACE.

FIG. 108.—THE LEFT NASAL BONE, NASAL SURFACE.



The **facial surface** is concave from above downward, convex from side to side, and near the centre is perforated by a small foramen, which transmits a small tributary to the facial vein. The posterior or **nasal surface,** covered in the recent state by mucous membrane, is concave laterally, and traversed by a longitudinal groove [sulcus ethmoidalis] for the anterior ethmoidal branch of the ophthalmic division of the fifth nerve. The short **superior border** is thick and serrated for articulation with the medial part of the nasal notch of the frontal. The **inferior border** is thin, and serves for the attachment of the lateral nasal cartilage. It is notched for the external nasal branch of the anterior ethmoidal nerve. The nasal bones of the two sides are united by their **medial borders,** forming the internasal suture. The contiguous borders are prolonged backward to form a crest which rests on the frontal spine and the anterior border of the perpendicular plate of the ethmoid. The **lateral border** articulates with the frontal process of the maxilla.

Blood-supply.—Arteries are supplied to this bone by the nasal branch of the ophthalmic, the frontal, the angular, and the anterior ethmoidal arteries.

Articulations.—With the frontal, maxilla, ethmoid, and its fellow of the opposite side.

Ossification.—Each nasal bone is developed from a single centre which appears about the eighth week in the membrane overlying the fronto-nasal cartilage. The cartilage, which is continuous with the ethmoid cartilage above and the lateral cartilage of the nose below, subsequently undergoes absorption as a result of the pressure caused by the expanding bone. At birth the nasal bones are nearly as wide as they are long, whereas in the adult the length is three times greater than the width.

THE MAXILLA

The **maxilla** or upper jaw-bone (figs. 109, 110, 111) is one of the largest and most important of the bones of the face. It supports the maxillary teeth and takes part in the formation of the orbit, the hard palate, and the nasal fossa. It is divisible into a **body** and four processes, of which two—the **frontal** and **zygomatic**—belong to the upper part, and the **palatine** and **alveolar** to the lower part of the bone.

The **body** is somewhat pyramidal in shape and hollowed by a large cavity known as the **sinus maxillaris** (antrum of Highmore), lined by mucous membrane in the recent state, and opening at the base of the pyramid into the nasal cavity, the zygomatic process forming the apex. The **anterior** (or facial) **surface** looks forward and outward and is marked at its lower part by a series of eminences which indicate the positions of the fangs of the teeth. The eminence produced by the fang of the canine tooth is very prominent and separates two fossæ. That on the medial side is the **incisive fossa,** and gives origin to the *alar* and *transverse portions* of the *nasalis,* and just above the socket of the lateral incisor tooth, to a slip of the *orbicularis oris;* on the lateral side is the **canine fossa,** from which the *caninus* (*levator anguli oris*) arises. Above the canine fossa, and close to the margin of the orbit, is the **infra-orbital foramen,** through which the terminal branches of the infra-orbital nerve and vessels emerge, and from the ridge immediately above the foramen the *quadratus labii superioris* takes origin. The medial margin of the anterior surface is deeply concave, forming the **nasal notch,** and is prolonged below into the **anterior nasal spine.**

A ridge of bone extending upward from the socket of the first molar tooth separates the anterior from the **infratemporal** (zygomatic) **surface.** This latter surface is convex and presents near the middle the orifices of the **posterior alveolar canals,** transmitting the posterior alveolar vessels and nerves. The posterior inferior angle, known as the **tuberosity** [tuber maxillare], is rough and is most prominent after eruption of the wisdom tooth. It gives attachment to a few fibres of the *internal pterygoid* muscle and articulates with the tuberosity of the palate.

The **orbital surface** [planum orbitale] is smooth, irregularly triangular, and forms the greater part of the floor of the orbit.

Anteriorly, it is rounded and reaches the orbital circumference for a short distance at the root of the nasal process; laterally is the rough surface for the zygomatic bone. The posterior border, smooth and rounded, forms the inferior boundary of the inferior orbital fissure. The medial border is nearly straight and presents behind the frontal process, a smooth rounded angle forming part of the circumference of the orbital orifice of the naso-lacrimal canal, and a notch which receives the lacrimal bone. The rest of the medial border is rough for articulation with the lamina papyracea of the ethmoid and orbital process of the palate bone.

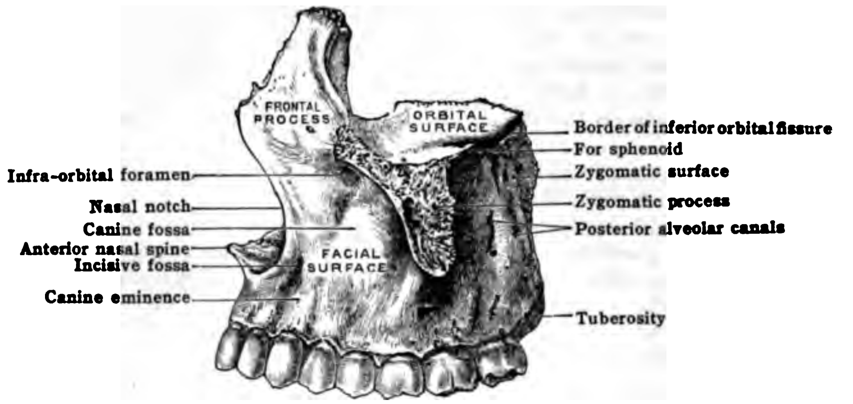
The orbital surface is traversed by the **infra-orbital groove,** which, commencing at the posterior border, deepens as it passes forward and finally becomes closed in to form the **infra-orbital canal.** It transmits the second division of the fifth nerve and the infra-orbital vessels and terminates on the anterior surface immediately below the margin of the orbit. From the infra-orbital, other canals —the **anterior** and **middle alveolar**—run downward in the wall of the antrum and transmit the anterior and middle alveolar vessels and nerves. Lateral to the commencement of the lacrimal canal is a shallow depression for the origin of the *inferior oblique.*

The **nasal surface** takes part in the formation of the lateral wall of the nasal fossa. It presents a large irregular aperture which leads into the antrum and, immediately in front of this, the **lacrimal groove,** directed downward, backward, and laterally into the inferior meatus of the nose. The groove is converted

into a canal by the lacrimal and inferior nasal concha and transmits the naso-lacrimal duct.

In front of the groove is a smooth surface crossed obliquely by a ridge, the **conchal crest**, for articulation with the inferior nasal concha. The surface below the crest is smooth, concave, and belongs to the inferior meatus; the surface above the crest extends on to the lower part of the frontal process and forms the wall of the atrium of the middle meatus. Behind the opening of the antrum the surface is rough for articulation with the vertical plate of the palate bone, and crossing it obliquely is a smooth groove converted by the palate into the **pterygo-palatine canal** for the passage of the (descending) palatine nerves and the descending palatine artery.

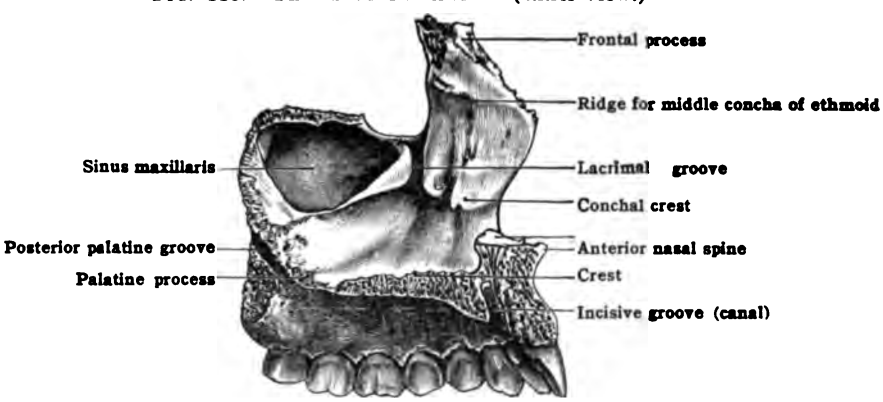
Fig. 109.—The Left Maxilla. (Outer view.)



The **frontal process,** somewhat triangular in shape, rises vertically from the **angle** of the maxilla. Its lateral surface is continuous with the anterior surface of the body, and gives attachment to the *orbicularis oculi*, the medial palpebral ligament and the *quadratus labii superioris* (*caput angulare*). The medial surface forms part of the lateral boundary of the nasal fossa and is crossed obliquely by a low ridge, known as the **agger nasi,** limiting the atrium of the middle meatus.

The hinder part of this surface rests on the anterior extremity of the labyrinth of the ethmoid and completes the maxillo-ethmoidal cells. The superior border articulates with the frontal; the anterior border articulates with the nasal bone; the posterior border is thick and vertically grooved, in continuation with the lacrimal groove, and lodges the lacrimal sac. The medial margin of the groove articulates with the lacrimal bone, and the junction of its lateral margin with the orbital surface is indicated by the **lacrimal tubercle.**

Fig. 110.—The Left Maxilla. (Inner view.)

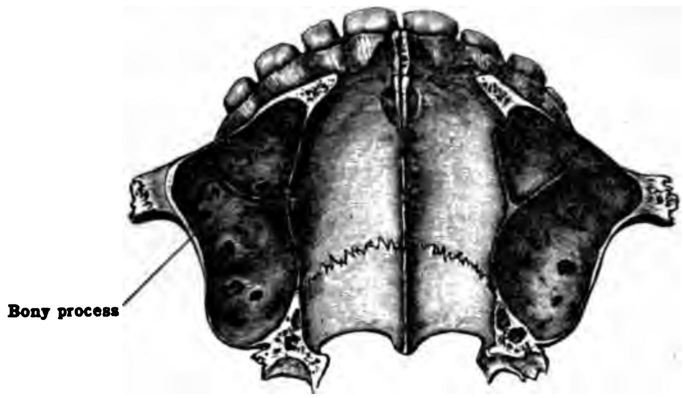


The **zygomatic process,** rough and triangular, forms the summit of the prominent ridge of bone separating the anterior and infratemporal surfaces. It articulates above with the zygomatic, and from its inferior angle a few fibres of the *masseter* take origin. The anterior and posterior surfaces are continuous with the anterior and infratemporal surfaces of the body.

The **palatine process** projects horizontally from the medial surface and, with the corresponding process of the opposite side, forms about three-fourths of the hard palate. The superior surface is smooth, concave from side to side, and

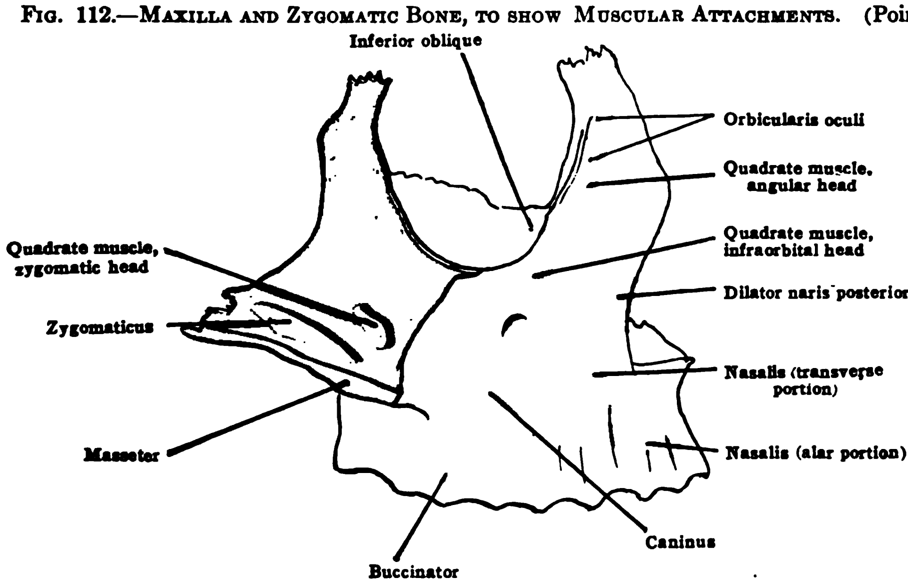
constitutes the larger part of the floor of the nasal fossa. The inferior surface is vaulted, rough, and perforated with foramina for nutrient vessels. Near its lateral margin is a longitudinal groove for the transmission of the vessels and nerves which issue at the posterior palatine canal and course along the lower aspect of the palate. When the bones of the two sides are placed in apposition, a large orifice may be seen in the middle line immediately behind the incisor teeth. This is the **incisive foramen,** at the bottom of which are four foramina. Two are small and arranged one behind the other exactly in the **meso-palatine suture.** These are the **foramina of Scarpa** and transmit the naso-palatine nerves, the left

FIG. 111.—SECTION OF MAXILLÆ TO SHOW THE FLOOR OF THE MAXILLARY ANTRUM. (Reduced ¼.)



passing through the anterior and the right through the posterior aperture. The lateral and larger orifices are the **foramina of Stenson,** representing the lower apertures of two passages by which the nose communicates with the mouth; they transmit some terminal branches of the descending palatine artery to the nasal fossæ, and lodge recesses of the nasal mucous membrane and remnants of Jacobson's organs.

FIG. 112.—MAXILLA AND ZYGOMATIC BONE, TO SHOW MUSCULAR ATTACHMENTS. (Poirier.)



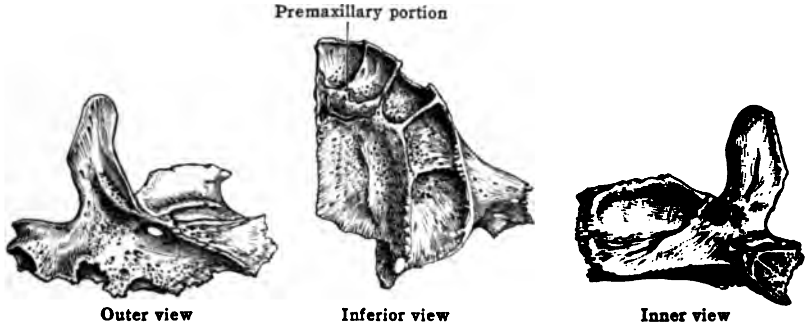
Running laterally from the incisive foramen to the space between the second incisor and canine tooth, an indistinct suture may sometimes be seen, indicating the line of junction of the maxillary and pre-maxillary portions of the bone. The **premaxilla** or incisive bone is the part which bears the incisor teeth and in some animals exists throughout life as an independent element. The posterior border of the palate process is rough and serrated for articulation with

the horizontal plate of the palate bone which completes the hard palate. The medial border joins with its fellow to form the **nasal crest** upon which the vomer is received. The more elevated anterior portion of this border is known as the **incisor crest**, and is continued forward into the **anterior nasal spine**. The septal cartilage of the nose rests on its summit and the anterior extremity of the vomer lies immediately behind it. At the side of the incisor crest is seen the upper aperture of the canal leading from the nose to the mouth (Stenson's canal), which in its course downward becomes a groove by a deficiency of its medial wall. Thus when the two bones are articulated a canal is formed (incisive) with the lower ends of two canals opening into it.

The **alevolar process** is crescentic in shape, spongy in texture, and presents cavities [alveoli dentales] in which the upper teeth are lodged. When complete there are eight tooth-cavities (alveoli), with wide mouths, gradually narrowing as they pass into the substance of the bone, and forming exact impressions of the corresponding fangs of the teeth. The pit for the canine tooth is the deepest; those for the molars are the widest, and present subdivisions. Along the lateral aspect of the alveolar process the *buccinator* arises as far forward as the first molar tooth.

The **maxillary sinus** or antrum of Highmore, as the air-chamber occupying the body of the bone is called, is somewhat pyramidal in shape, the **base** being represented by the nasal or medial surface, and the **apex** corresponding to the zygomatic process. In addition it has four walls: the superior is formed by the orbital plate, and the inferior by the alveolar ridge. The anterior wall corresponds to the anterior surface of the maxilla, and the posterior is formed by the infratemporal surface. The medial boundary or base presents a very irregular

FIG. 113.—THE MAXILLA AT BIRTH.



orifice at its posterior part; this is partially filled in by the vertical plate of the palate bone, the uncinate process of the ethmoid, the maxillary process of the inferior nasal concha, and a small portion of the lacrimal bone. Even when these bones are in their relative positions, the orifice is very irregular in shape, and requires the mucous membrane to form the definite rounded aperture (or apertures, for they are often multiple) known as the **opening of the sinus** through which the cavity communicates with the middle meatus of the nose.

The cavity of the sinus varies considerably in size and shape. In the young, it is small and the walls are thick: as life advances it enlarges at the expense of its walls, and in old age they are often extremely thin, so that occasionally the cavity extends even into the substance of the zygomatic bone. The floor of the sinus is usually very uneven, due to prominences corresponding to the roots of the molar teeth. In most cases the bone separating the teeth from the sinus is very thin, and in some cases the roots project into it. The teeth which come into closest relationship with the sinus are the first and second molars, but the sockets of any of the teeth lodged in the maxilla may, under diseased conditions, communicate with it. As a rule, the cavity of the sinus is single, but occasionally specimens are seen in which it is divided by bony septa into chambers, and it is not uncommon to find recesses separated by bony processes. The roof of the sinus presents near its anterior aspect what appears to be a thick rib of bone; this is hollow and corresponds to the infra-orbital canal.

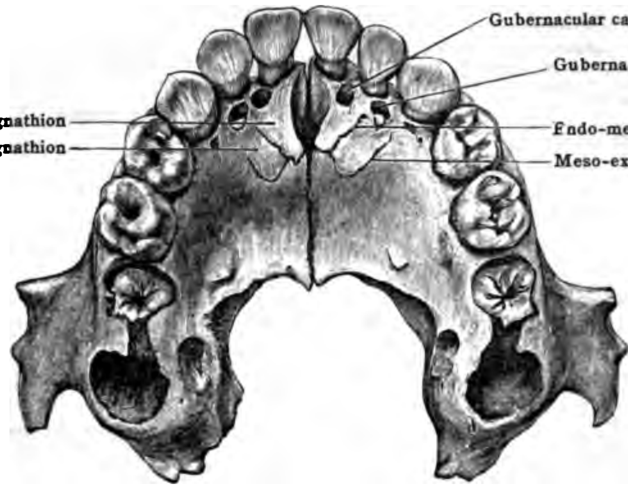
The most satisfactory method of studying the relation of the bones closing in the base of the antrum is to cut away the lateral wall of the cavity (see fig. 128).

Blood-supply.—The maxilla is a very vascular bone and its arteries are numerous and large. They are derived from the infra-orbital, alveolar, descending palatine, spheno-palatine, ethmoidal, frontal, nasal, and facial vessels.

Articulations.—With the frontal, nasal, lacrimal, ethmoid, palate, vomer, zygomatic, inferior nasal concha and its fellow of the opposite side. Occasionally it articulates with the great wing, and the pterygoid process, of the sphenoid.

Ossification.—The maxilla is developed from several centres which are deposited in membrane during the second month of intrauterine life. Several pieces are formed which speedily fuse, so that at birth, with the exception of the incisor fissure separating the maxilla from the premaxilla, there is no trace of the composite character of the bone. The centres of ossification comprise—(1) the **malar**, which gives rise to the portion of bone outside the infra-orbital canal; (2) the **maxillary**, from which the greater part of the body and the frontal process are developed; (3) the **palatine**, forming the hinder three-fourths of the palatal process and adjoining part of the nasal wall; (4) the **premaxillary**, giving rise to the independent premaxillary bone (os incisivum), which lodges the incisor teeth and completes the anterior fourth of the hard palate. In the early stages of growth the premaxilla may consist of two pieces arising from two centres of ossification which Albrecht has named as follows:—the *endognathion*, or medial division for

FIG. 114.—MAXILLÆ AT THE END OF THE FIRST DENTITION IN BOTH OF WHICH THE SUTURES BETWEEN MAXILLA AND PREMAXILLA, AND BETWEEN THE TWO PARTS OF THE PREMAXILLA, ARE SEEN.



the central incisor, and the *mesognathion*, or lateral division for the **lateral** incisor; the rest of the maxilla is named the *exognathion;* (5) the **prepalatine**, corresponding to the **infra-vomerine** centre of Rambaud and Renault, forms a portion of bone interposed between the premaxillary in front and the palatine process behind. It gives rise to a part of the nasal surface and completes the medial wall of the incisive canal.

At birth the sinus is narrow from side to side and does not extend laterally to any appreciable extent between the orbit and the alveoli of the teeth. During the early years of life it gradually enlarges, but does not attain its full growth until after the period of the second dentition.

THE PALATE

The **palate bone** [os palatinum] (figs. 115, 116) forms the posterior part of the hard palate, the medial wall of the nasal fossa between the maxilla and the medial pterygoid plate, and, by its orbital process, the hinder part of the floor of the orbit. It is somewhat L-shaped and presents for examination **a horizontal** part and a **perpendicular** part; at their point of junction is the **pyramidal process,** and surmounting the top of the vertical plate are the **orbital** and **sphenoidal** processes, separated by the **spheno-palatine notch.**

The **horizontal** part resembles the palatine process ofthe maxilla, but is much shorter. The **superior surface** is smooth, concave from side to side, and forms the back part of the floor of the nasal fossa; the **inferior surface** completes the hard palate behind and presents near its prosterior border a transverse ridge which gives attachment to the *tensor veli palatini* muscle.

The **anterior border** is rough for articulation with the palatine process of the maxilla; the posterior is free, curved, and sharp, giving attachment to the soft palate. Medially it is thick and broad for articulation with its fellow of the opposite side, forming a continuation of the crest of the palatal processes of the maxillæ and supporting the vomer. The posterior extremity of the crest is the **posterior nasal spine**, from which the *azygos uvulæ* arises. Laterally, at its junction with the perpendicular part, it is grooved by the lower end of the pterygo-palatine canal.

The **perpendicular** part is longer and thinner than the horizontal plate. The **lateral surface** is in relation with the maxilla and is divided into two parts by

a vertical groove which forms with the maxilla the **pterygo-palatine canal** for the transmission of the anterior palatine nerve and the descending palatine artery. The part of the surface in front of the groove articulates with the nasal surface of the maxilla and overlaps the orifice of the antrum by the **maxillary process,** a variable projection on the anterior border. Behind the groove the surface is rough for articulation with the maxilla below and the medial pterygoid plate above.

FIG. 115.—PALATE BONE (LEFT). (Medial view.)

The **medial** or **nasal surface** presents two nearly horizontal ridges separating three shallow depressions. Of the depressions, the lower forms part of the inferior meatus of the nose, and the limiting ridge or **conchal (inferior turbinate) crest** articulates with the inferior nasal concha. Above this is the depression forming part of the middle meatus, and the ridge or **ethmoidal (superior turbinate) crest,** constituting its upper boundary, articulates with the middle nasal concha.

FIG. 116.—PALATE BONE. (Posterior view.)

The upper groove is narrower and deeper than the other two and forms a large part of the superior meatus of the nose. The anterior border of the vertical plate is thin and bears the **maxillary process,** a tongue-like piece of bone, which extends over the opening of the maxillary sinus from behind. This border is continuous above with the orbital process. The **posterior border** is rough and articulates with the anterior border of the medial pterygoid plate. It is continuous superiorly with the sphenoidal process.

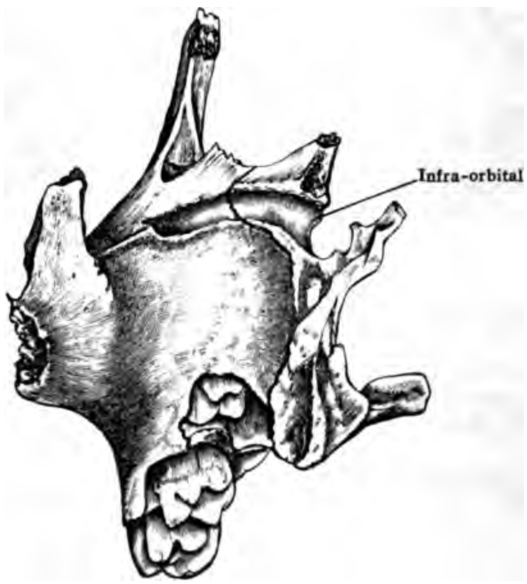
The **pyramidal process** or **tuberosity** fits into the notch between the lower extremities of the pterygoid plates and presents posteriorly three grooves. The middle, smooth and concave, completes the pterygoid fossa, and gives origin to a few fibres of the *internal pterygoid;* the medial and lateral grooves are rough for articulation with the anterior border of the corresponding pterygoid plate. Inferiorly, close to its junction with the horizontal plate, are the openings of the **greater palatine** and **smaller palatine canals,** of which the latter are the smaller and less constant; they transmit the palatine nerves. Medially the pyramidal process gives origin to a few fibres of the *superior constrictor* of the pharynx, and laterally a small part appears in the zygomatic fossa between the tuberosity of the maxilla and the pterygoid process of the sphenoid.

The **sphenoidal process,** the smaller of the two processes surmounting the vertical part, curves upward and medially and presents three surfaces and two borders. The **superior surface** is in contact with the body of the sphenoid, and the top of the medial pterygoid plate, where it completes the pharyngeal canal. The **medial** or **inferior surface** forms part of the lateral

wall and roof of the nasal fossa, and at its medial end touches the ala of the vomer. The **lateral surface** looks forward and laterally into the pterygo-palatine (spheno-maxillary) fossa. Of the two borders, the posterior is thin and articulates with the medial pterygoid plate; the anterior border forms the posterior boundary of the **spheno-palatine** foramen.

The **orbital process** is somewhat pyramidal in shape, and presents for examination five surfaces, three of which—the posterior, anterior, and medial—are articular and the rest non-articular. The **posterior** or **sphenoidal surface** is small and joins the anterior surface of the body of the sphenoid; the **medial** or **ethmoidal** articulates with the labyrinth of the ethmoid; and the **anterior** or **maxillary**, which is continuous with the lateral surface of the perpendicular part, is joined with the maxilla. Of the two non-articular surfaces, the **superior** or **orbital**, directed upward and laterally, is slightly concave, and forms the posterior angle of the floor of the orbit; the **lateral** or **zygomatic**, smooth and directed lateral, looks into the pterygo-palatine (spheno-maxillary) and zygomatic fossæ, and forms the anterior boundary of the spheno-palatine foramen. The process is usually hollow and the cavity completes one of the posterior ethmoidal cells or communicates with the sphenoidal sinus.

FIG. 117.—MAXILLA AND PALATE BONES SHOWING HOW THE INFRA-ORBITAL GROOVE RUNS OUTWARD ALMOST AT RIGHT ANGLES FROM THE NEIGHBOURHOOD OF THE SPHENO-PALATINE FORAMEN ON THE BACK OF THE MAXILLA AND THE ORBITAL PROCESS OF THE PALATE. POSTERIOR VIEW. (E. Fawcett.)



Between the orbital and sphenoidal processes is the **spheno-palatine notch,** converted by the body of the sphenoid, into a complete foramen. It leads from the pterygo-palatine fossa into the back part of the nasal cavity close to its roof, and transmits the medial branches from the spheno-palatine ganglion and the spheno-palatine vessels.

Blood-supply.—The palate bone receives branches from the descending palatine and the spheno-palatine arteries.

Articulations.—With the sphenoid, maxilla, vomer, inferior nasal concha, ethmoid, and its fellow of the opposite side.

Ossification.—The palate is ossified in membrane from a single centre which appears about the eighth week at the angle between the horizontal and perpendicular parts. At birth the two parts are nearly equal in length, but as the nasal fossæ increase in vertical depth, the perpendicular part is lengthened until it becomes about twice as long as the horizontal part.

THE ZYGOMATIC

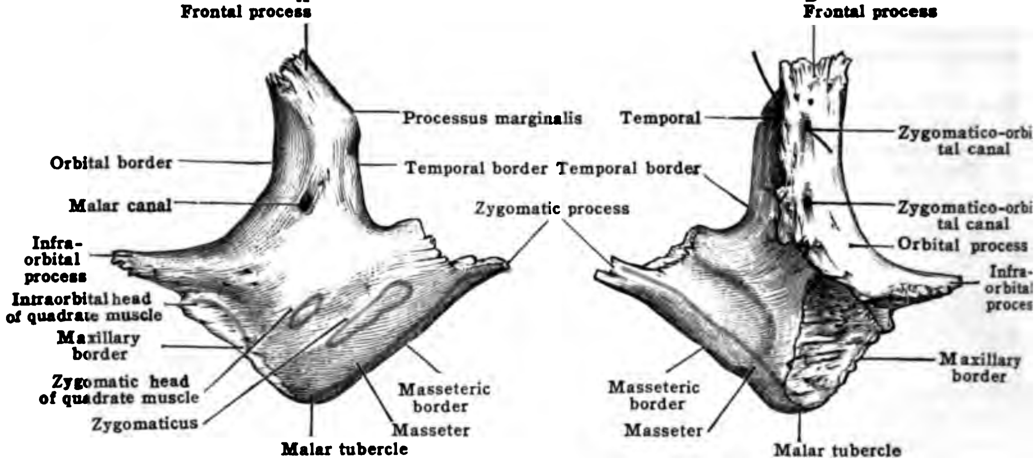
The **zygomatic** [os zygomaticum] or **malar bone** (fig. 118) forms the prominence known as the cheek and joins the zygomatic process of the temporal with the maxilla. It is quadrangular in form with the angles directed vertically and horizontally. The **malar** (or external) **surface** is convex and presents one or two small orifices for the transmission of the zygomatico-facial nerves and vessels. It is largely covered by the *orbicularis oculi* and near the middle is slightly elevated to form the **malar tuberosity,** which gives origin to the *zygomaticus* and *zygomatic head* of quadrate muscle of upper lip.

The **temporal** (or internal) **surface** is concave and looks into the temporal and infratemporal fossæ; it is excluded from the orbit by a prominent curved plate

of bone, the **orbital process,** which forms the anterior boundary of the temporal fossa. The upper part gives origin to a few fibres of the *temporal* muscle, while at the lower part is a large rough area for articulation with the zygomatic process of the maxilla.

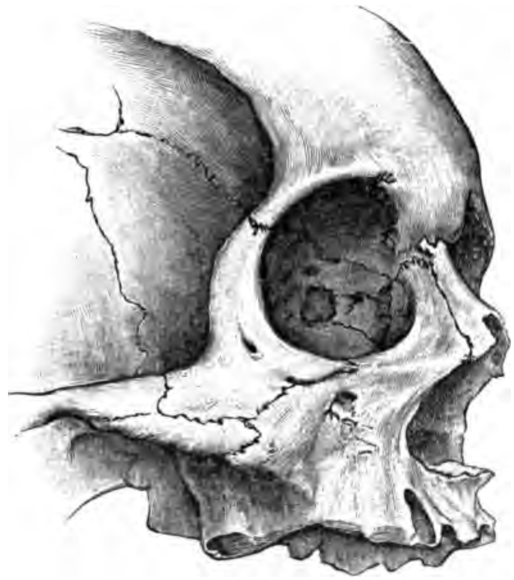
The **orbital process** is placed at right angles to the remaining part of the bone and forms the anterior portion of the lateral wall of the orbit. On the **orbital**

Fig. 118.—The Left Zygomatic Bone.
A, the malar surface. B, the temporal and orbital surfaces.



surface of the process are seen the foramina of two **zygomatico-orbital canals,** which transmit the zygomatico-facial and zygomatico-temporal branches of the zygomatic branch of the fifth, together with two small arteries from the lacrimal. In some cases, however, the canal is single at its commencement on the orbital plate and bifurcates as it traverses the bone. The rough free edge of the

Fig. 119.—Skull showing the Right Malar Bone divided into Two Parts by a Horizontal Suture. (From a specimen in the Museum of University College, London.)



process articulates above with the zygomatic border of the great wing of the sphenoid, and below with the maxilla. When the orbital process is large, it excludes the great wing of the sphenoid from articulation with the maxilla, and the border then presents near the middle a short, non-serrated portion

which closes the anterior extremity of the inferior orbital (spheno-maxillary) fissure.

All the four angles of the zygomatic bone have distinguishing features. The superior, forming the **fronto-sphenoidal process**, is the most prominent, and is serrated for articulation with the zygomatic process of the frontal; the anterior or **infra-orbital process**, sharp and pointed, articulates with the maxilla and occasionally forms the superior boundary of the infra-orbital foramen; the posterior or **temporal process** is blunt and serrated mainly on its medial aspect for articulation with the zygomatic process of the temporal; the inferior angle, blunt and rounded, is known as the **malar tubercle**.

Of the four borders, the **orbital** is the longest and extends from the fronto-sphenoidal to the infra-orbital process. It is thick, rounded, and forms more than one-third of the circumference of the orbit; the **temporal border**, extending from the fronto-sphenoidal to the temporal process, is sinuously curved and gives attachment to the temporal fascia. Near the frontal angle is usually seen a slight elevation, the **processus marginalis**, to which a strong slip of the fascia is attached; the **masseteric** border, thick and rough, completes the lower edge of the zygomatic arch and gives origin to the anterior fibres of the *masseter;* the **maxillary** border, rough and concave, is connected by suture with the maxilla, and near the margin of the orbit gives origin to the infra-orbital head of the *quadratus labii superioris.*

Blood-supply.—The arteries of the zygomatic are derived from the infra-orbital, lacrimal, transverse facial, and deep temporal arteries.

Articulations.—With the maxilla, frontal, temporal, and sphenoid.

Ossification.—The zygomatic is ossified in membrane from three centres which appear in the eighth week of intra-uterine life. The three pieces, which have received the names of *premalar, postmalar,* and *hypomalar,* unite about the fifth month. Occasionally the primary nuclei fail to coalesce, and the bone is then represented in the adult by two or three portions separated by sutures. In those cases in which the premalar and postmalar unite and the hypomalar remains distinct, the suture is horizontal; if the independent portion is the premalar, then the suture is vertical. The bipartite zygomatic has been observed in skulls obtained from at least a dozen different races of mankind, but because of the greater frequency in which it occurs in the crania of the Japanese (seven per cent.), the name of *os Japonicum* has been given to it.

THE MANDIBLE

The **mandible** [mandibula] or lower jaw-bone (figs. 120, 121) is the largest and strongest bone of the face. It supports the mandibular teeth, and by means of a pair of condyles, moves on the skull at the mandibular fossæ of the temporal bones. It consists of a horizontal portion—the **body**—strongly curved, so as to somewhat resemble in shape a horseshoe, from the ends of which two branches or **rami** ascend almost at right angles.

The **body** is marked in the middle line in front by a faint groove which indicates the **symphysis** or place of union of the two originally separate halves of the bone. This ends below in the elevation of the chin known as the **mental protuberance,** the lowest part of which is slightly depressed in the centre and raised on each side to form the **mental tubercle.** Each half of the mandible presents two surfaces and two borders. On the **lateral surface,** at the side of the symphysis, and below the incisor teeth, is a shallow depression, the **incisor fossa,** from which the *mentalis* and *the incisivus labii inferioris* muscle arise; and more laterally, opposite the second bicuspid tooth, and midway between the upper and lower margins, is the **mental foramen,** which transmits the mental nerve and vessels. Below the foramen is the **oblique line,** extending backward and upward from the mental tubercle to the anterior border of the ramus; it divides the body into an upper or **alveolar** part and a lower or **basilar** part, and affords attachment to the *quadratus labii inferioris* and the *triangularis oris.*

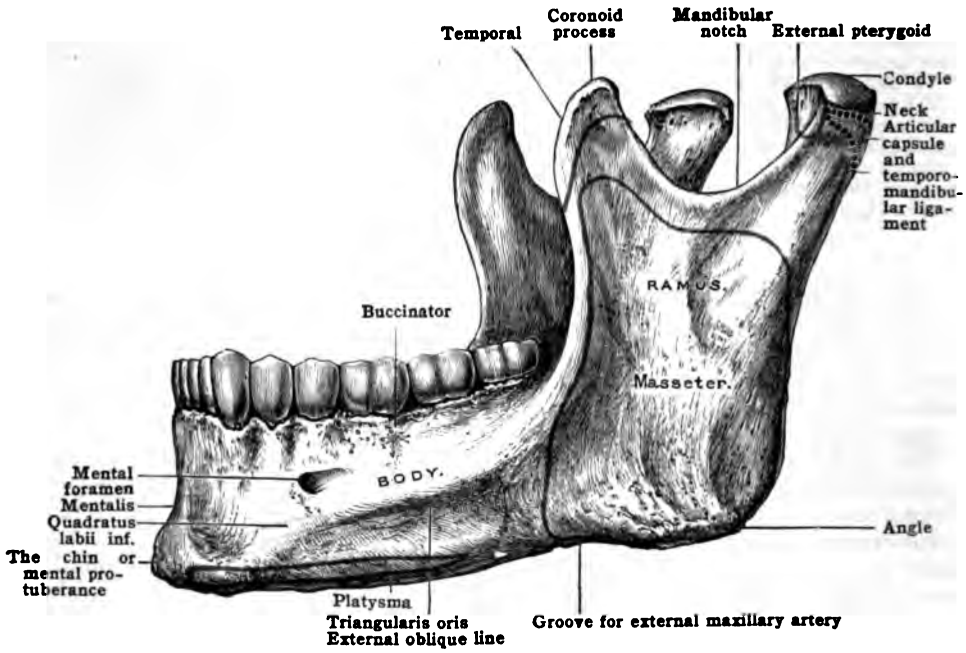
The **medial surface** presents at the back of the symphysis four small projections, called the **mental spine** (genial tubercles). These are usually arranged in two pairs, one above the other; the upper comprising a pair of prominent spines, gives origin to the *genio-glossi,* and the lower, represented in some bones by a median ridge or only a slight roughness, gives origin to the *genio-hyoid* muscles. At the side of the symphysis near the inferior margin is an oval depression, the **digastric fossa,** for the insertion of the *digastric* muscle. Commencing below the mental spine, and extending upward and backward to the ramus, is the **mylo-hyoid line,** which becomes more prominent as it approaches the alveolar border; it gives attachment along its whole length to the *mylo-hyoid* muscle, at its posterior fifth to the *superior constrictor* of the pharynx, and at the posterior extremity to the pterygo-mandibular raphe. Above this line at the side of the symphysis is a smooth depression [fovea sublingualis] for the sublingual gland, and below it, farther back, is another for the submaxillary gland.

The **alveolar part** or superior border is hollowed out into eight **sockets** or alveoli. These are conical in shape and form an exact counterpart of the roots of the teeth which they contain. From the lateral aspect of the alveolar process, as far forward as the first molar tooth, the *buccinator* muscle takes origin.

The **base** or inferior border is thick and rounded. In the anterior part of its extent it gives attachment to the *platysma*, and near its junction with the ramus is a groove for the external maxillary artery which here turns upward into the face.

The **ramus** is thinner than the body and quadrilateral in shape. The lateral surface is flat, gives insertion to the *masseter*, and at the lower part is marked by several oblique ridges for the attachment of tendinous bundles in the substance of the muscle. The medial surface presents near the middle the **mandibular** (inferior dental) **foramen,** leading into the **mandibular** (inferior dental) **canal** which traverses the bone and terminates at the mental foramen on the lateral surface of the body. From the canal, which in its posterior two-thirds is nearer to the medial, and in its anterior third nearer to the lateral, surface of the mandible,

FIG. 120.—THE MANDIBLE. (Lateral view.)



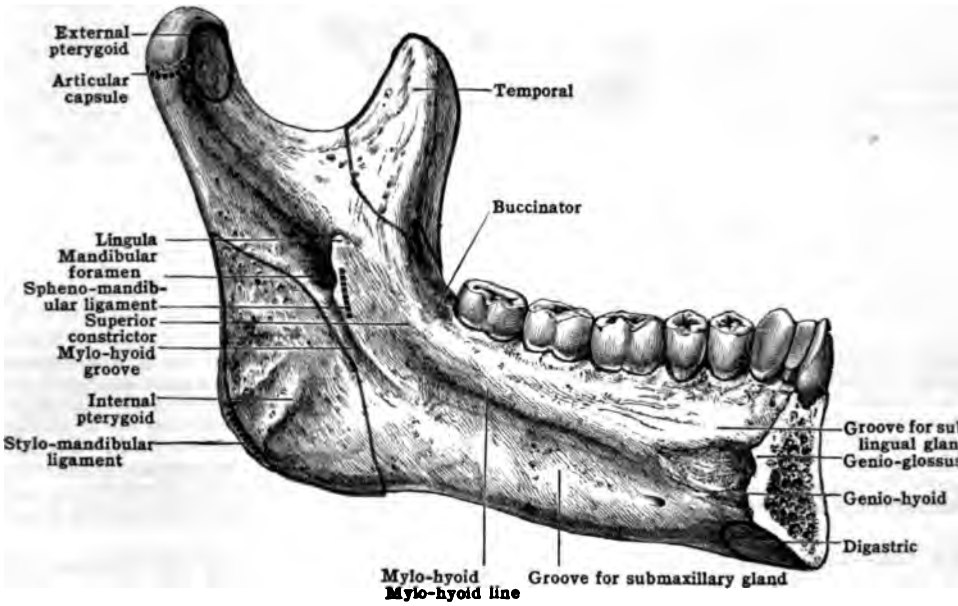
a series of small channels pass upward to the sockets of the posterior teeth and transmit branches of the inferior alveolar (dental) vessels and nerve; in front of the mental foramen a continuation of the canal extends forward and conveys the vessels and nerves to the canine and incisor teeth. The mandibular foramen is bounded medially by a sharp margin forming the **lingula** (mandibular spine), which gives attachment to the spheno-mandibular ligament.

The posterior margin of the lingula is notched. This notch forms the commencement of a groove, the **mylo-hyoid groove** [sulcus mylohyoideus], which runs obliquely downward and forward and lodges the mylo-hyoid nerve and artery, and, in the embryo, Meckel's cartilage. Behind the spine is a rough area for the insertion of the *internal pterygoid* muscle.

The posterior border of the ramus is thick and rounded, and in meeting the inferior border of the ramus forms the **angle** of the jaw, which is rough, obtuse, usually everted, and about 122° in the adult; the angle gives attachment to the stylo-mandibular ligament. The inferior border is thick, rounded, and continuous with the base. The anterior border is continuous with the oblique line, whilst the upper border presents two processes separated by a deep concavity, the **mandibular** (sigmoid) **notch.** Of the processes, the anterior is the **coronoid;** the posterior, the **condylar.**

The **condylar process** consists of the **condyle** [capitulum mandibulæ] and the narrowed portion by which it is supported, the **neck.** The **condyle** is oval in shape, with its long axis transverse to the upper border of the ramus, but oblique with regard to the median axis of the skull, so that the lateral extremity, which presents the **condylar tubercle** for the temporo-mandibular ligament of the temporo-mandibular articulation, is a little more forward than the medial extremity. The convex surface of the condyle is covered with cartilage in the recent

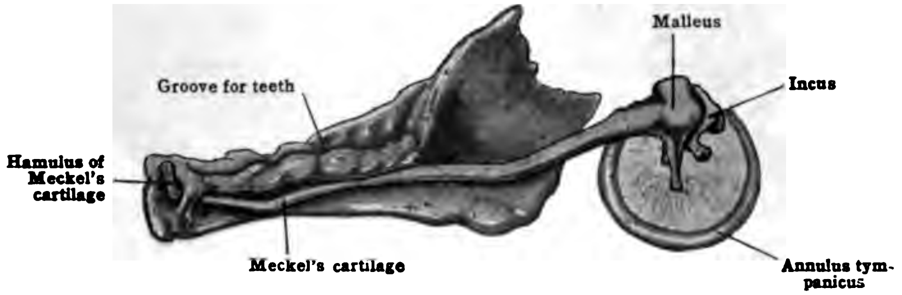
FIG. 121.—THE MANDIBLE. (Medial view.)



state, and rests in the mandibular fossa; the **neck** is flattened from before backward, and presents, in front, a depression [fovea pterygoidea] for the insertion of the *external pterygoid* muscle.

The **coronoid process,** flattened and triangular, is continued upward from the anterior part of the ramus. The lateral surface is smooth and gives insertion to the *temporal* and *masseter* muscles; the medial surface is marked by a ridge which descends from the tip and becomes continuous with the posterior part of the mylo-hyoid line. On the medial surface, as well as on the tip of the coronoid

FIG 122—MANDIBLE SHOWING RELATIONS OF MECKEL'S CARTILAGE IN HUMAN FŒTUS OF 8 CM. CROWN-RUMP LENGTH. (After Kollmann, Handatlas der Entwickelungsgeschichte.)



process, the *temporal* muscle is inserted. The **mandibular notch,** the deep semilunar excavation separating the coronoid from the condylar process, is crossed by the masseteric nerve and vessels.

Blood-supply.—Compared with other bones, the superficial parts of the mandible are not so freely supplied with blood. The chief artery is the inferior alveolar which runs in the mandibular canal, and hence, as the bone is exposed to injury and sometimes actually laid bare in its alveolar portion, it often necroses, especially if the artery is involved at the same time.

7

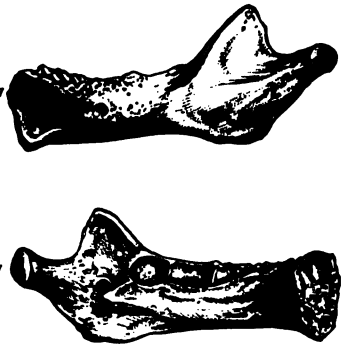
Ossification.—The mandible is mainly formed by ossification in the fibrous tissue investing the cartilage of the first branchial arch or Meckel's cartilage, although a small portion of the cartilage itself is directly converted into bone.

It is now generally admitted that the lower jaw is developed in membrane as a single skeletal element. The centre of ossification appears in the outer aspect of Meckel's cartilage and gives rise to the bony plate known as the *dentary*. This plate extends forward right up to the middle line in front, and from it a shelf grows upward for the support of the tooth germs.

Fig. 123.—The Mandible at Birth.

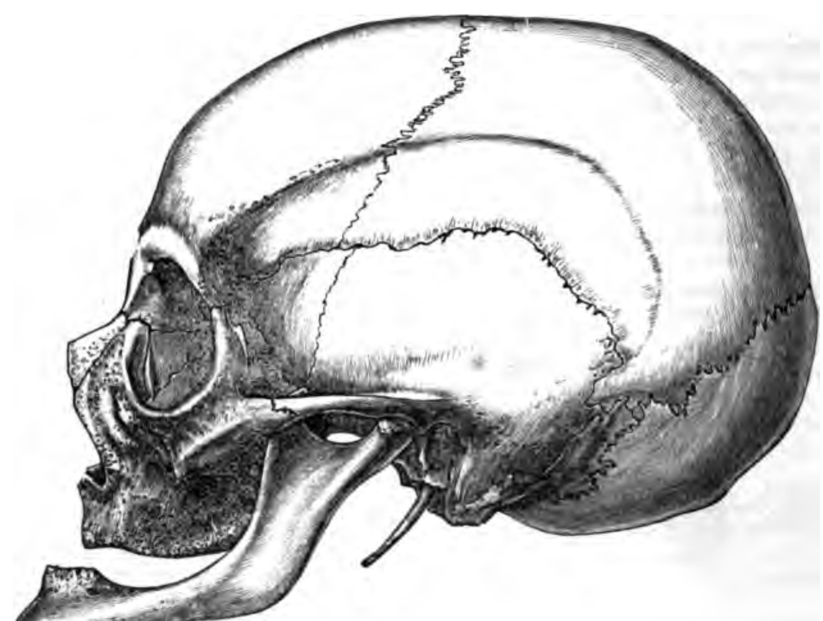
Outer view

Inner view



Meckel's cartilage lies below and medial to the dentary plate, and the inferior alveolar nerve passes forward between the two structures. Meckel's cartilage itself takes some small part in the formation of the lower jaw. Ossification from the primary nucleus invades the cartilage at a point opposite the interval between the first and second tooth germs, and the resulting bone contributes to the formation of the alveolar margin opposite these two teeth. Behind this point the cartilage atrophies except in so far as it helps to form the spheno-mandibular ligament and the malleus and incus. Behind the symphysis the anterior extremity of the cartilage does not enter into the formation of the jaw, but it usually persists throughout fœtal

Fig. 124.—The Skull of a Woman Eighty-three Years Old, to show the Changes in the Mandible and Maxilla.



life as one or two small, rounded, cartilaginous masses. Occasionally they become ossified and give rise to accessory ossicles in this situation. The lamella of bone situated on the medial side of Meckel's cartilage, corresponding to the distinct splenial element in some animals, arises in man as an extension from the dentary element.

In connection with the condylar and coronoid processes, cartilaginous masses are developed. These do not, however, indicate separate elements, but are adaptations to the growth of the lower jaw. They are ossified by an extension from the surrounding membrane bone.

The process of ossification of the lower jaw commences very early, between the sixth and eighth week, and proceeds rapidly, so that by the fourth month the various parts are formed.

Age-changes.—At birth the mandible is represented by two nearly horizontal troughs of bone, lodging unerupted teeth, and joined at the symphysis by fibrous tissue. The body is mainly alveolar, the basal part being but little developed; the condyle and the upper edge of the symphysis are nearly on a level; the mental foramen is nearer the lower than the upper margin, and the angle is about 175°. The inferior alveolar nerve lies in a shallow groove between the splenial and dentary plates.

During the first year osseous union of the two halves takes place from below upward, but is not complete until the second year. After the first dentition, the ramus forms with the body of the mandible an angle of about 140°, and the mental foramen is situated midway between the upper and lower borders of the bone opposite the second milk-molar. In the adult, the angle formed by the ramus and body is nearer to a right angle, and the mental foramen is opposite the second bicuspid, so that its relative position remains unaltered after the first dentition. In old age, after the fall of the teeth, the alveolar margin is absorbed, the angle formed by the ramus and body is again increased, and the mental foramen approaches the alveolar margin. In a young and vigorous adult the mandible is, with the exception of the petrous portion of the temporal, the densest bone in the skeleton; in old age it becomes exceedingly porous, and often so soft that it may easily be broken.

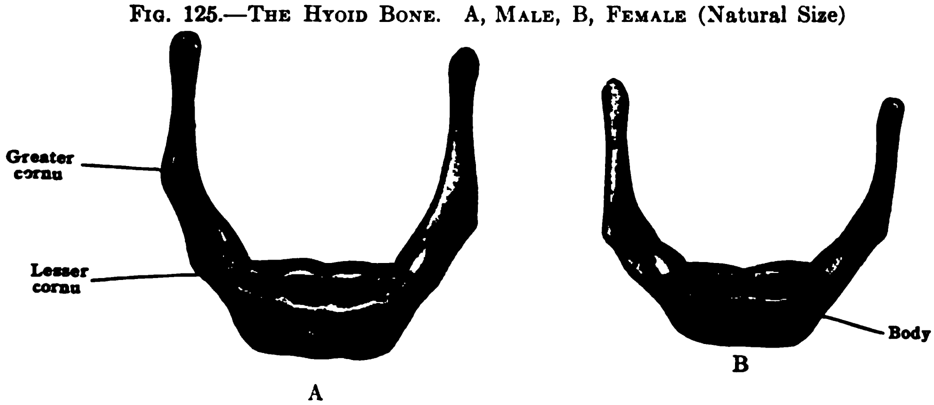
THE HYOID BONE

The **hyoid bone** [os hyoideum] or os linguæ (fig. 125), situated in the anterior part of the neck between the chin and the thyreoid cartilage, supports the tongue and gives attachment to numerous muscles. It is suspended from the lower extremities of the styloid processes of the temporal bones by two slender bands known as the **stylo-hyoid ligaments,** and is divisible into a **body** and two pairs of processes, the **greater** and **lesser cornua.**

The **body,** constituting the central portion of the bone, is transversely placed and quadrilateral in form. It is compressed from before backward and lies obliquely so that the anterior surface looks upward and forward and the posterior surface in the opposite direction.

The **anterior surface** is convex and divided by a horizontal ridge into a superior and an inferior portion. Frequently it also presents a vertical ridge crossing the former at right angles, and just above the point of intersection is the **glosso-hyal**

FIG. 125.—THE HYOID BONE. A, MALE, B, FEMALE (Natural Size)

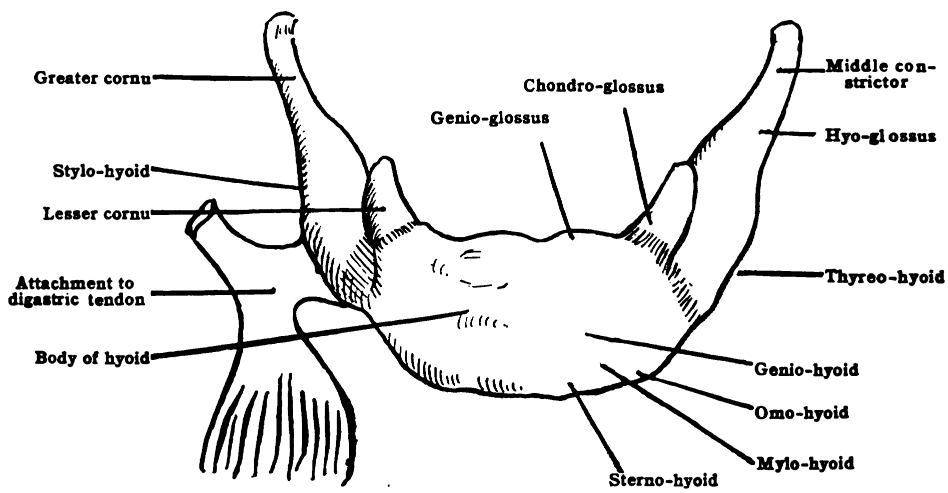


process, the vestige of a well-developed process in this situation in the hyoid bone of some of the lower animals (reptiles and the horse). In this way four spaces or depressions for muscular attachments are marked off, two on either side of the middle line. The **posterior surface** is deeply concave and separated from the epiglottis by the thyreo-hyoid membrane, and by some loose areolar tissue. The membrane passes upward from the thyreoid cartilage to be attached to the **superior border,** and interposed between it and the concavity on the back of the body is a small synovial bursa. The **inferior border,** thicker than the upper, gives insertion to muscles. The **lateral borders** are partly in relation with the greater cornua, with which they are connected, up to middle life, by synchondrosis, but after this period, usually by bone.

The **greater cornua** projects upward and backward from the sides of the body. They are flattened from above downward, thicker near their origin, and terminate posteriorly in a rounded tubercle to which the thyreo-hyoid ligament is attached.

The **lesser cornua** are small conical processes projecting upward and backward opposite the lines of junction between the body and the greater cornua, and by their apices give attachment to the stylo-hyoid ligaments; they are connected to the body by fibrous tissue. Professor Parsons has shown that a joint with a synovial cavity is common between the smaller and geater cornua. The lesser cornua are sometimes partly or even completely cartilaginous in the adult.

FIG. 126.—HYOID BONE ENLARGED TO SHOW MUSCULAR ATTACHMENTS. (After F. G. Parsons.)



The **muscles** attached to each half of the hyoid bone may be enumerated as follows:—

Body............ Genio-hyoid, genio-glossus, mylo-hyoid, sterno-hyoid, omo-hyoid, stylo-hyoid, thyreo-hyoid and hyo-glossus.
Greater cornu.....Thyreo-hyoid, middle constrictor, hyo-glossus, and digastric.
Lesser cornu...... Chondro-glossus, and middle constrictor.

Ossification.—In the early months of intra-uterine life the hyoid bone is composed of hyaline cartilage and is directly continuous with the styloid processes of the temporal bones. Ossification takes place from six centres, of which two appear in the central piece of cartilage, one on either side of the middle line, either just before or just after birth; soon after their appearance, however, they coalesce to form the body of the bone (basi-hyal). The centre for each of the greater cornua (thyreo-hyals) appears just about the time of birth, and for each of the lesser cornua (cerato-hyals) some years after birth, even as late as puberty. (F. G. Parsons.) The greater cornua and the body unite in middle life; the lesser cornua rarely ankylose with the body and only in advanced age. Professor Parsons has shown, however, that the lesser cornua more frequently unite with the greater cornua.

THE SKULL AS A WHOLE

The skull, formed by the union of the cranial and facial bones already described, may now be considered as a whole. Taking a general view, it is spheroidal in shape, smooth above, compressed from side to side, flattened and uneven below, and divisible into six regions: a superior region or vertex, a posterior or occipital region, an anterior or frontal region, an inferior region or base, and two lateral regions.

(1) THE SUPERIOR REGION

Viewed from above (*norma verticalis*) the skull presents an oval outline with the broader end behind, and includes the **frontal, parietals,** and the **interparietal** portion of the **occipital.** In a skull of average width the zygomatic arches are visible, but in very broad skulls they are obscured.

The **sutures** of the vertex are:—

The **metopic**, which is, in most skulls, merely a median fissure in the frontal bone just above the **glabella**; occasionally it involves the whole length of the bone. It is due to the persistence of the fissure normally separating the two halves of the bone in the infant.

The **sagittal** is situated between the two parietals, and extends from the bregma to the lambda.

The **coronal** lies between the frontal and parietals, and extends from pterion to pterion.

The **lambdoid** is formed by the parietals and interparietal portion of the occipital. It extends from asterion to asterion.

The **occipital** suture is only present when the interparietal exists as a separate element (figs. 70 and 71).

The more important points are:—

The **bregma**, which indicates the situation of the frontal (greater) fontanelle, and marks the confluence of the coronal, the sagittal, and, when present, the metopic sutures.

The **lambda**, where the sagittal enters the lambdoid suture; it marks the situation of the occipital (lesser) fontanelle.

The **obelion**, a little anterior to the lambda, is usually indicated by a median or two lateral foramina.

(2) The Posterior Region

Viewed from behind (*norma occipitalis*) the skull is somewhat pentagonal in form. Of the five angles, the superior or median is situated in the line of the sagittal suture; the two upper lateral angles coincide with the parietal eminences and the two lower with the mastoid processes of the temporal bones. Of the sides, four are somewhat rounded, and one, forming the basal line, running between the mastoid processes, is flattened.

The centre is occupied by the lambda, and radiating from this point are three sutures, the **sagittal**, and the two parts of the **lambdoid**. Each half of the lambdoid suture bifurcates at the mastoid portion of the temporal bone, the two divisions constituting **the parieto-mastoid** and **occipito-mastoid** sutures; the point of bifurcation is known as the **asterion.**

In the lower part of the view is seen the **external occipital protuberance** (inion), the occipital crest, and the three pairs of nuchal lines, which give it a rough and uneven appearance. The **occipital point** is the point of the occiput furthest from the glabella in the median plane. It is situated above the external occipital protuberance.

(3) The Lateral Region

The **lateral region** (*norma lateralis*) (fig. 127) is somewhat triangular in shape, being bounded above by a line extending from the zygomatic process of the frontal, along the temporal line to the lateral extremity of the superior nuchal line of the occipital bone; this forms the base of the triangle. The two sides are represented by lines drawn from the extremities of the base to the angle of the jaw. It is divisible into two portions, one in front, the other behind, the eminentia articularis [tuberculum articulare]. The posterior portion presents, in a horizontal line from behind forward, the mastoid portion of the temporal, with its process and foramen, the external auditory meatus, the centre of which is known as the **auricular point**, the mandibular fossa, and the condyle of the mandible.

In the anterior portion are three fossæ, (a) temporal, (b) infratemporal, (c) pterygo-palatine (spheno-maxillary), and two fissures, the inferior orbital (spheno-maxillary) and pterygo-palatine.

(a) The **temporal fossa**, somewhat semilunar in shape, is bounded *above* and *behind* by the temporal line, in *front* by the frontal, zygomatic, and great wing of sphenoid, and *laterally* by the zygomatic arch, by which it is separated superficially from the infratemporal fossa; more deeply the infratemporal ridge separates the two fossæ.

The **fossa** is formed by parts of five bones, the zygomatic, temporal, parietal, frontal, great wing of sphenoid, and is traversed by six sutures, coronal, spheno-zygomatic, spheno-squamosal, spheno-parietal, squamosal, and spheno-frontal. The point where the temporal ridge is crossed by the coronal suture is the **stephanion**, and the region where the frontal, sphenoid, temporal, and parietal meet is the **pterion.** The latter is frequently occupied in the adult by the **epipteric** bone.

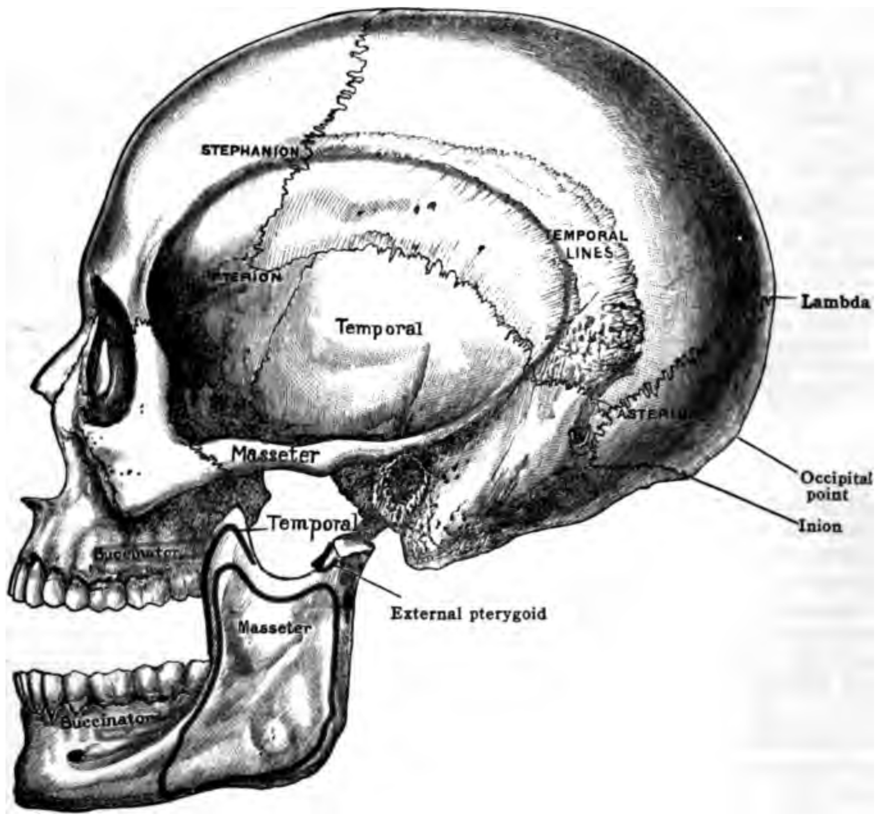
The temporal fossa is concave in front, convex behind, filled by the temporal muscle, and roofed in by a strong glistening aponeurosis, the **temporal fascia**, which serves to bind down the muscle.

(b) The **infratemporal fossa** (zygomatic fossa), irregular in shape, is situated below and to the medial side of the zygoma, covered in part by the ramus of the mandible. It is bounded *in front* by the lower part of the medial surface of the zygomatic, and by the infratemporal surface of the maxilla, on which are seen the orifices of the posterior superior alveolar canals; *behind* by the posterior border of the lateral pterygoid plate, the spine of the sphenoid, and the articular tubercle; *above* by the infratemporal ridge, a small part of the squamous portion of

the temporal, the great wing of the sphenoid perforated by the foramen ovale and foramen spinosum; *below* by the alveolar border of the maxilla; *laterally* by the ramus of the mandible and the zygoma formed by zygomatic and temporal; *medially* by the lateral pterygoid plate, a line from which to the spine of the sphenoid separates the infratemporal fossa from the base of the skull. It contains the lower part of the temporal muscle and the coronoid process of the mandible, the external and internal pterygoids, the internal maxillary vessels, and the mandibular division of the fifth nerve with numerous branches. At its upper and medial part are seen the inferior orbital and pterygo-palatine fissures.

The **inferior orbital** (or spheno-maxillary) **fissure** is horizontal in position, and lies between the maxilla and the great wing of the sphenoid; laterally it is usually completed by the zygomatic, though in some cases the sphenoid joins the maxilla, and in this way excludes the zygomatic bone from the fissure; medially it is terminated by the infratemporal surface of the orbital process of the palate bone. Through this fissure the orbit communicates with the pterygo-palatine (spheno-maxillary), infratemporal, and temporal fossæ. It transmits the infra-orbital nerve and vessels, the zygomatic nerve, ascending branches from the spheno-palatine ganglion to the orbit, and a communicating vein from the ophthalmic to the pterygoid plexus.

FIG. 127.—THE SKULL. (Norma lateralis.)

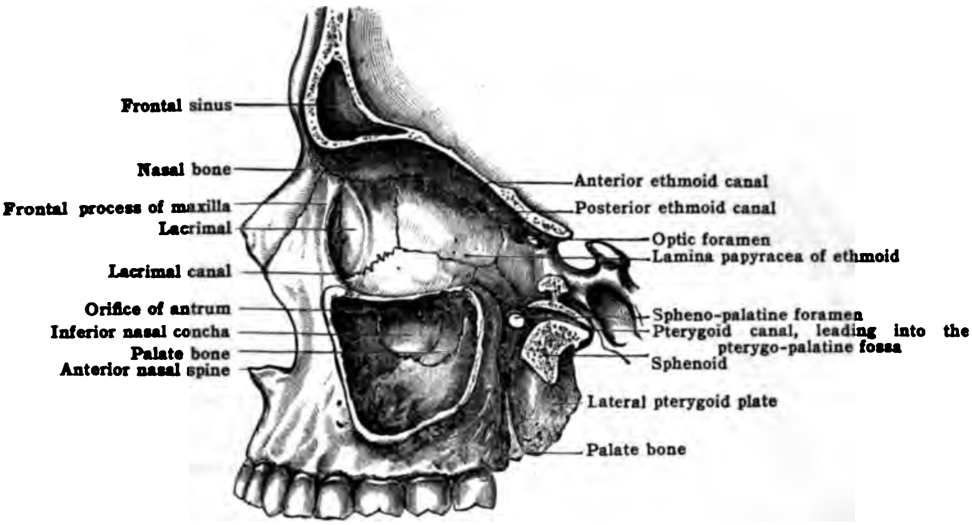


The **pterygo-palatine** (pterygo-maxillary) **fissure** forms a right angle with the inferior orbital fissure and is situated between the maxilla and the anterior border of the pterygoid process of the sphenoid. At its lower angle, where the two lips of the fissure approximate, the lateral pterygoid plate occasionally articulates with the maxilla, but they are usually separated by a thin portion of the pyramidal process of the palate. The pterygo-palatine fissure, which serves to connect the infratemporal fossa with the pterygo-palatine fossa, is bounded medially by the perpendicular part of the palate; it transmits branches of the internal maxillary artery, and the corresponding veins, to and from the pterygo-palatine fossa.

(c) The **pterygo-palatine** (spheno-maxillary) **fossa** is a small space, of the form of an inverted pyramid, situated at the angle of junction of the inferior orbital (spheno-maxillary) with the pterygo-palatine (pterygo-maxillary) fissure, below the apex of the orbit. It is bounded *in front* by the infratemporal surface of the maxilla; *behind*, by the base of the pterygoid process and the lower part of the anterior surface of the great wing of the sphenoid; *medially* by the perpendicular part of the palate with its orbital and sphenoidal processes; *above* by the lower surface of the body of the sphenoid. Three fissures terminate in it—viz., the superior orbital, pterygo-palatine, and inferior orbital; through the superior orbital fissure it communicates with the cranium, through the pterygo-palatine fissure with the infratemporal fossa, through the inferior orbital fissure with the orbit, and through the spheno-palatine foramen on the medial wall it communicates with the upper and back part of the nasal fossa. In-

cluding the **spheno-palatine** foramen six foramina open into the fossa. Of these, three are on the posterior wall: enumerated from without inward, and from above downward, they are the **foramen rotundum**, the **pterygoid (Vidian) canal**, and the **pharyngeal** (pterygo-palatine) **canal**. The apex of the pyramid leads below into the **pterygo-palatine canal** and the **accessory palatine canals** which branch from it; and anteriorly is the orifice of the **infra-orbital canal**. The fossa contains the spheno-palatine ganglion, the maxillary nerve, and the terminal part of the internal maxillary artery, and the various foramina and canals in relation with the fossa serve for the transmission of the numerous branches which these vessels and nerves give off.

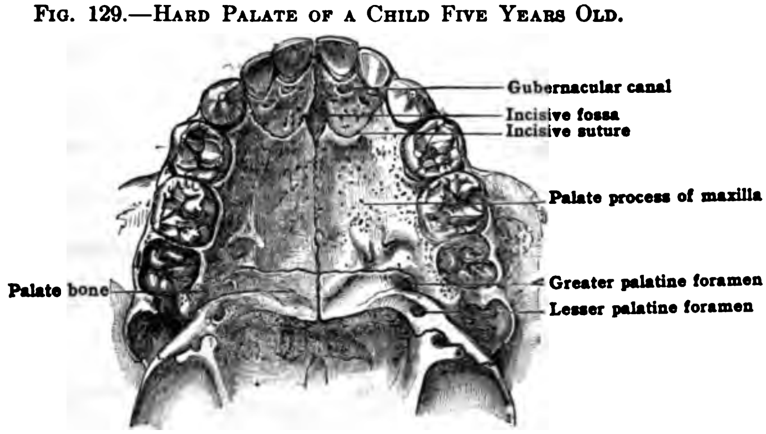
FIG. 128.—A SECTION OF THE SKULL SHOWING THE MEDIAL WALL OF THE ORBIT, THE MEDIAL WALL OF THE ANTRUM, AND THE PTERYGO-PALATINE FOSSA.



(4) INFERIOR REGION OR EXTERNAL BASE OF SKULL

The **external base** of the skull (*norma basilaris*) (figs. 130, 131) extends from the incisor teeth to the occipital protuberance, and is bounded on each side by the alveolar arch, the zygomatic, the zygoma, the temporal, and the superior nuchal line of the occipital bone. It is very uneven and, excluding the lower jaw, divisible into three portions: (a) anterior, (b) middle or subcranial, and (c) posterior or suboccipital.

FIG. 129.—HARD PALATE OF A CHILD FIVE YEARS OLD.



(a) The **anterior division** consists of the hard palate, the alveolar arch, and the choanæ (posterior nares).

When the skull is inverted, the hard palate stands at a higher level than the rest, and is bounded anteriorly and laterally by the alveolar ridges containing the teeth. The bones appearing in the intermediate space are the premaxillary and palatine portions of the maxillæ and the horizontal parts of the palate bones.

Fig. 130.—The Skull. (Norma basilaris.)

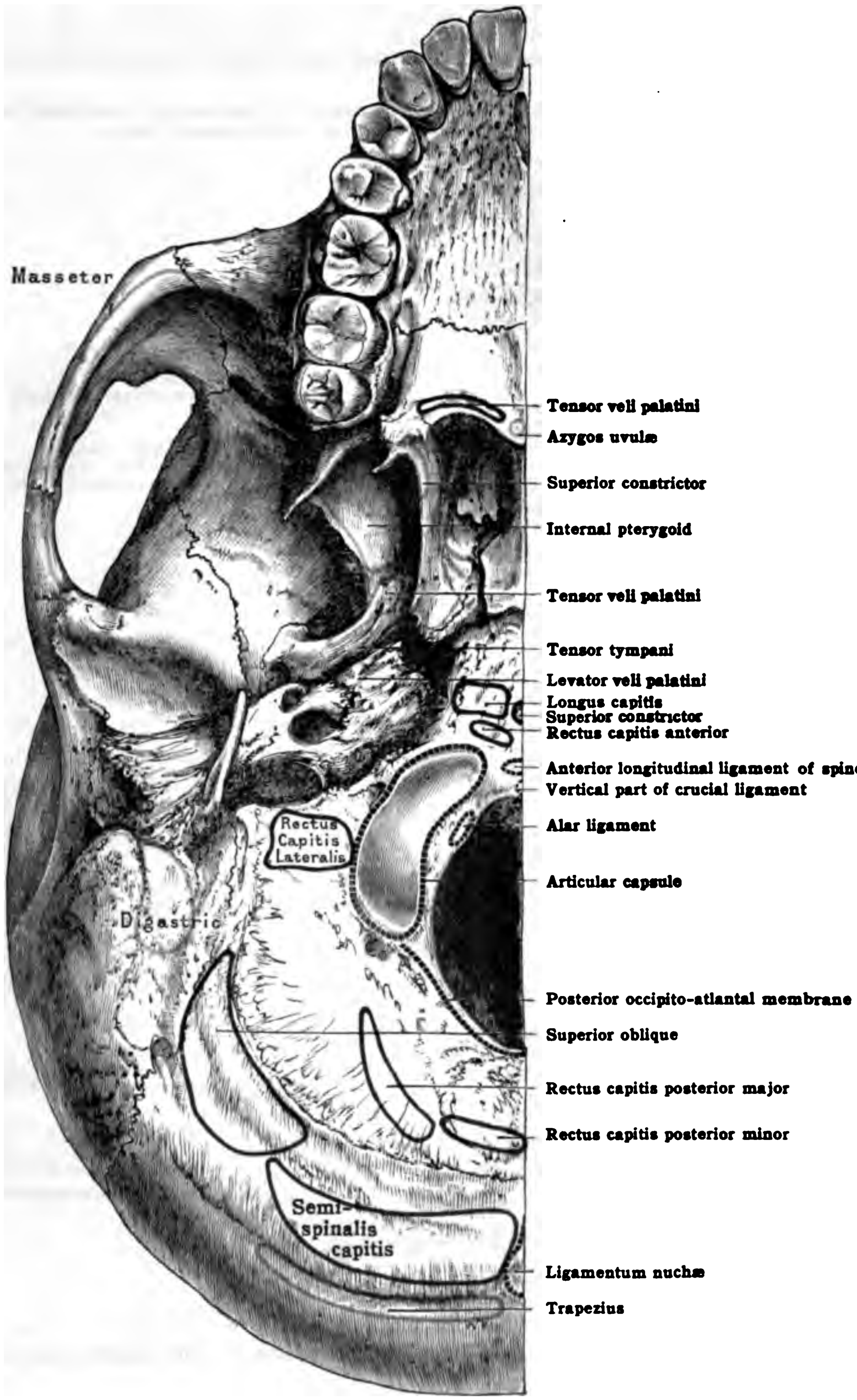
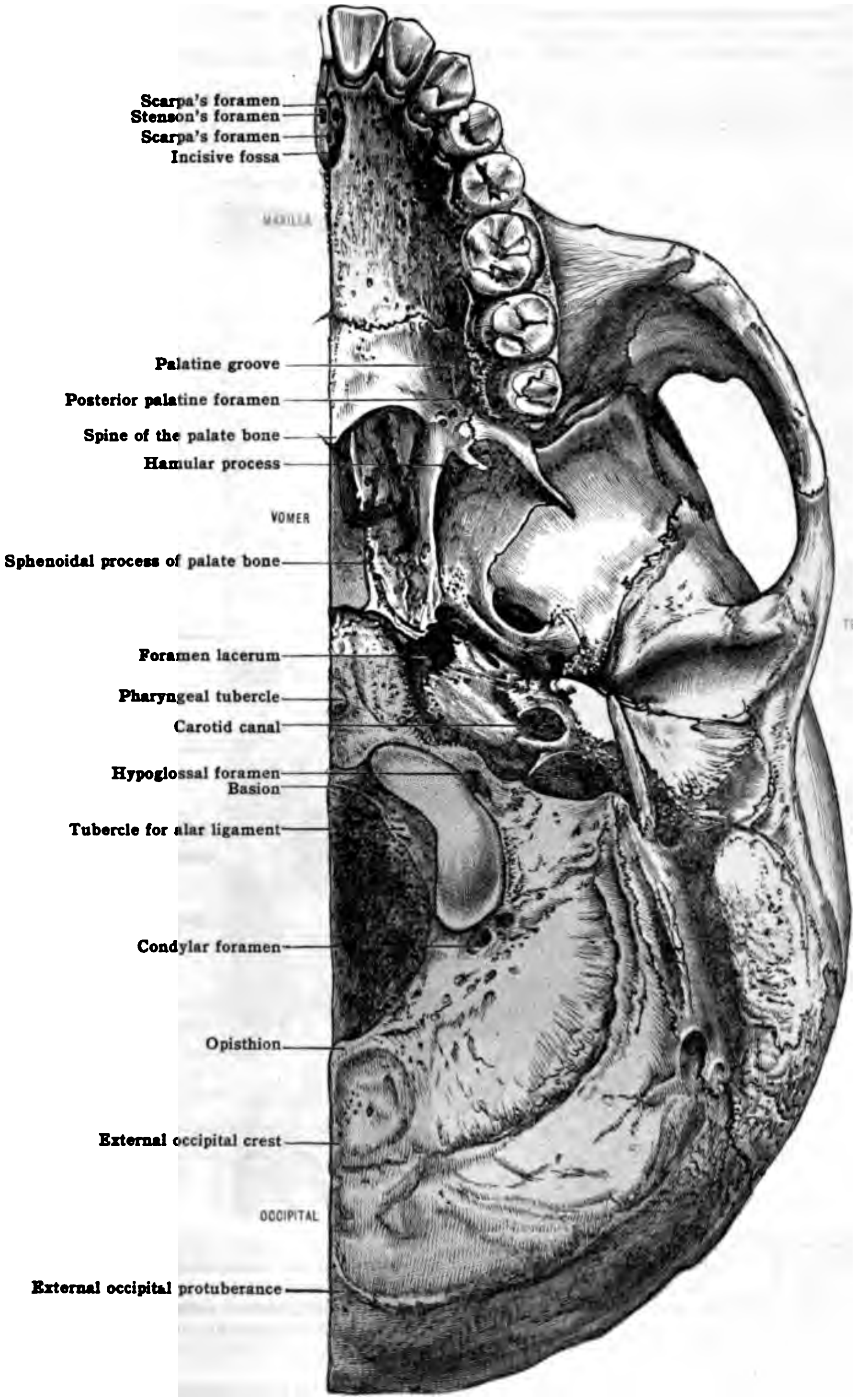


Fig. 131.—The Skull. (Norma basilaris.)



They are rough for the attachment of the muco-periosteum, and near the posterior margin is the ridge for the fibrous expansion of the *tensor veli palatini.* The following points are readily recognised (fig. 129):—

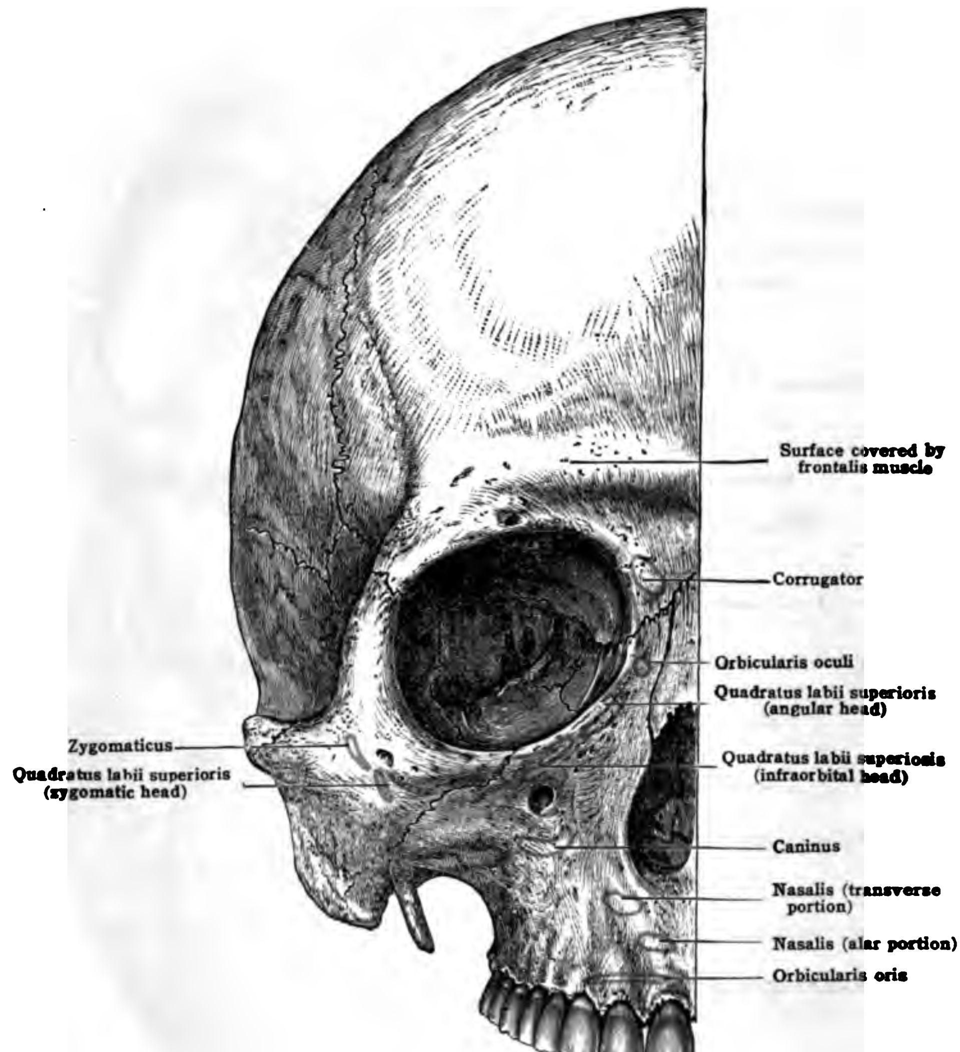
The **meso-palatine suture** commences at the alveolar point, traverses the incisive fossa, and terminates at the posterior nasal spine.

The **transverse palatine suture,** between the palate bones and palatine processes of the maxillæ.

In young skulls the **incisive sutures,** and behind the incisor teeth four small openings known as the **gubernacular canals** (see figs. 114 and 129).

The incisive fossa containing the termination of four canals: two small orifices, **foramina of**

Fig. 132.—The Skull. (Norma facialis.)



Scarpa, situated one behind the other in the meso-palatine suture; and two larger openings, the **foramina of Stenson.** The foramina of Scarpa transmit the naso-palatine nerves, and those of Stenson are in relation (embryonic) with the organs of Jacobson.

At the posterior angles of the hard palate are the **greater palatine foramina,** through which the descending palatine vessels and the anterior palatine nerves emerge on to the palate; a thin lip of bone separates them from the **lesser palatine foramen** in the tuberosity of the palate bone on each side, for the posterior palatine nerve.

The **hamular process** of the medial pterygoid plate is the most posterior limit of the hard palate.

At the posterior extremity of each alveolar ridge is the **tuberosity of the maxilla,** and between it and the palate bone is a foramen (variable in size and sometimes absent), the **middle palatine foramen,** for the middle palatine nerve. This foramen is often included under the lesser palatine foramina (BNA).

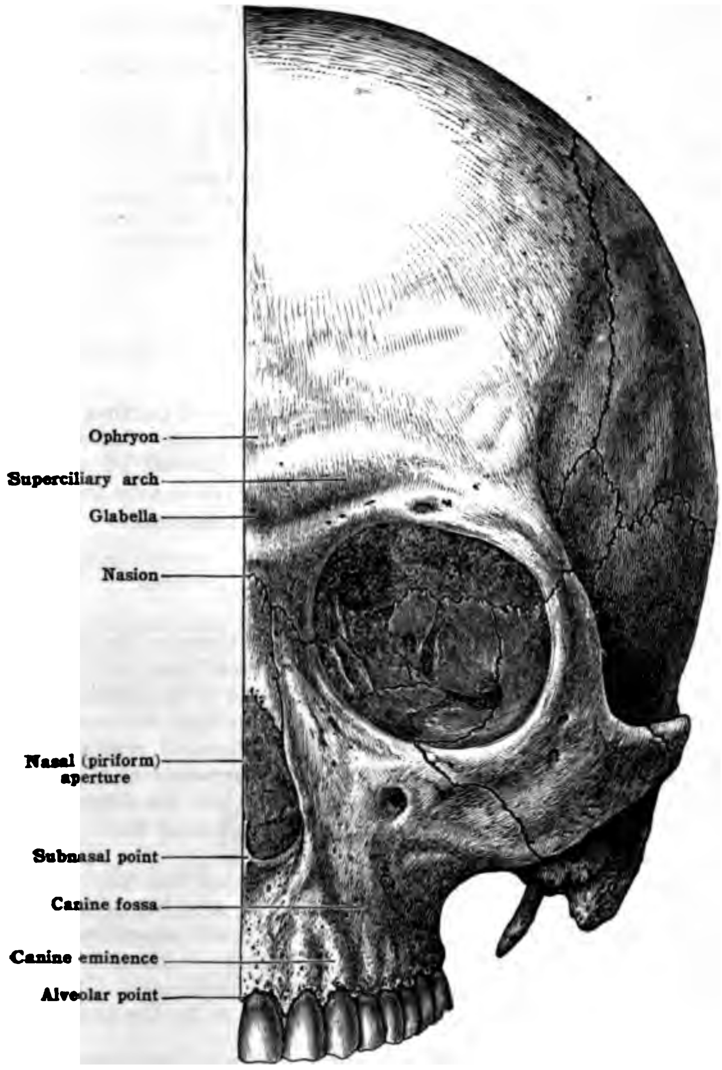
Behind the hard palate are the **choanæ** (posterior nares), separated from each other by the vomer. Each is bounded laterally by the medial pterygoid plate; below by the horizontal plate of the palate bone; above by the under surface of the body of the sphenoid, with the ala of the vomer and a portion of the sphenoidal process of the palate bone.

Lateral to the choanæ there is on each side a vertical fossa lying between the pterygoid plates. It extends upward to the under surface of the great wings of the sphenoid; it is completed anteriorly by the coalescence of the pterygoid plates and below by the pyramidal process of the palate bone. It contains the following points of interest:—

An elongated furrow, the **scaphoid fossa**, for the *tensor veli palatini* muscle and the cartilage of the Eustachian tube.

The general cavity of the **pterygoid fossa** which lodges the *tensor veli palatini* and *internal pterygoid* muscles.

FIG. 133.—THE SKULL. (Norma facialis.)



Frequently there is a notch in the lateral pterygoid plate close beside the foramen ovale.
The posterior termination of the pterygoid (Vidian) canal.

If a line be drawn across the base of the skull from one preglenoid tubercle to the other, it will fall immediately behind the lateral pterygoid plate and bisect the foramen spinosum on each side. A second transverse line, drawn across the **opisthion** or posterior margin of the foramen magnum, will fall behind the mastoid processes. The space between these arbitrary lines may be called the *subcranial region;* that behind the second line, the *suboccipital region.*

(b) The **subcranial region** is separated from the infratemporal fossa by a line drawn from the posterior margin of the lateral pterygoid plate to the spine of the

sphenoid. It is formed by the inferior surface of the basilar process of the occipital and the body of the sphenoid, the petrous portion of the temporal bone, a small piece of the squamosal portion, the posterior part of the great wing of the sphenoid, and the condylar portions of the occipital bone. It presents the following points for examination (Figs. 95, 131):—

The **pharyngeal tubercle.**

The **foramen magnum** and the **occipital condyles.** The most anterior point of the foramen is termed the **basion,** and the most posterior point the **opisthion.**

On each side will be seen:—The **hypoglossal foramen** for the hypoglossal nerve and a meningeal branch of the ascending pharyngeal artery.

The **condylar fossa** with the condylar foramen (this foramen is not constant).

The under aspect of the **jugular process,** from which the *rectus capitis lateralis* takes origin.

The **foramen lacerum** and the orifice of the **pterygoid (Vidian) canal.**

The **canalis musculo-tubarius** for the *tensor tympani* muscle and Eustachian tube.

The **carotid canal.**

The quadrilateral area for the origin of the *levator veli palatini* and *tensor tympani* muscles.

The **canaliculus cochleæ,** or ductus perilymphaticus.

The **jugular foramen** and **fossa** for the glosso-pharyngeal, vagus, and spinal accessory nerves, the internal jugular vein, and a meningeal branch of the ascending pharyngeal artery.

The **tympanic canaliculus** for Jacobson's nerve (tympanic branch of glossopharyngeal).

The **spine** of the sphenoid; this is sometimes fifteen millimetres in length.

The **mandibular fossa** with the **petro-tympanic fissure.** This lodges the anterior process of the malleus, the tympanic twig of the internal maxillary artery. A small passage beside it, the **canal of Huguier,** conducts the chorda tympani nerve from the tympanum.

The **external auditory meatus.**

The **auricular** or **tympano-mastoid fissure.**

The **tympanic plate** and **vaginal** process.

The **styloid process.**

The **stylo-mastoid foramen** for the stylo-mastoid artery and the exit of the facial nerve and, in some cases, the auricular branch of the vagus.

The **mastoid process** with the digastric and occipital grooves.

(c) The **suboccipital region** is largely formed by the tabular portion of the occipital bone with its ridges and areas for muscular attachment. Laterally a small part of the mastoid portion of the temporal is seen, pierced by a small foramen, of variable size, the **mastoid foramen,** which transmits a vein from the transverse (lateral) sinus and a meningeal branch of the occipital artery.

(5) The Anterior Region

The **anterior region** (*norma facialis*) (figs. 132, 133) comprises the anterior end of the cranium or forehead, and the skeleton of the face; also the cavities known as the **orbits,** formed by the junction of the two parts of this region, and the **nasal fossæ,** situated on either side of the septum of the nose.

The upper part or forehead, narrowest between the temporal crests about half an inch above the zygomatic processes of the frontal, presents at this level the two **transverse sulci;** above are the **frontal eminences,** below the **superciliary arches,** and still lower the supra-orbital margins, interrupted near their medial ends by the supra-orbital notches.

Below the forehead are the openings of the **orbits,** bounded laterally by the zygomatic bones constituting the prominences of the cheeks, and between them the bridge of the nose, formed by the nasal bones and the frontal processes of the maxillæ. Below the nasal bones is the **apertura piriformis** or **anterior nasal aperture,** leading into the nasal fossæ. The teeth form a conspicuous feature in this view of the skull, the outline of which is completed below by the **mandible.**

The **bones** entering into formation of the *norma facialis* are:—the frontal, nasals, lacrimals, orbital surfaces of the small and the great wings, and a portion of the body of the sphenoid, the laminæ papyraceæ of the ethmoids, the orbital processes of the palate bones, the zygomatics, maxillæ, inferior nasal conchæ, and the mandible.

The **sutures** are numerous, and for the most part unimportant:—

The **transverse** suture (fig. 133) extends from one zygomatic process of the frontal to the other. The upper part of the suture is formed by the frontal bone; below are the zygomatic, great and small wings of the sphenoid, lamina papyracea, lacrimal, maxillary, and nasal bones. A portion of this complex suture, lying between the sphenoidal and frontal bones, appears in the anterior cranial fossa.

Other fissures are the internasal, naso-maxillary, inter-maxillary and zygomatico-maxillary. The small sutures seen in the orbit are described with that cavity.

The **foramina** are:—the supra-orbital, infra-orbital, optic, zygomatico-facial, and mental; the naso-lacrimal canal; the ethmoidal canals; and the inferior and superior orbital fissures.

The following points may also be noticed:—

The **glabella**, a smooth space between the converging superciliary arches.

The **ophryon**, the most anterior point of the metopic suture.

The **nasion**, the middle of the naso-frontal suture.

The **subnasal point**, the middle of the inferior border of the pyriform aperture at the base of the nasal spine.

The **alveolar point**, the centre of the anterior margin of the upper alveolar arch.

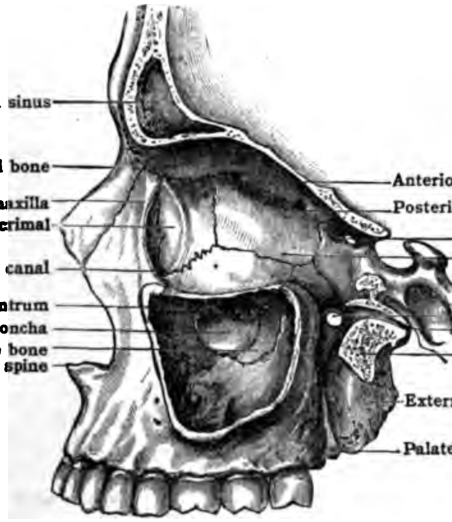
THE ORBITS

The **orbits** [orbitæ] (fig. 134) are two cavities of pyramidal shape, with their bases directed forward and laterally and their apices backward and medially; their medial walls are nearly parallel, but their lateral walls diverge so as to be nearly at right angles to each other. Each cavity forms a socket for the eyeball and the muscles, nerves, and vessels associated with it.

Seven bones enter into formation of its walls, viz., the frontal, zygomatic, sphenoid, ethmoid, lacrimal, palate, and maxilla; but as three of these—the frontal, sphenoid, and ethmoid—are single median bones which form parts of each cavity, there are only eleven bones represented in the two orbits. Each orbit presents for examination four walls, a circumference or base, and an apex.

The **superior wall** or roof, vaulted and smooth, is formed mainly by the orbital plate of the frontal and is completed posteriorly by the small wing of the sphenoid. At the lateral angle it presents the **lacrimal fossa** for the lacrimal gland, and at the medial angle a depression or a spine for the pulley of the *superior oblique* muscle.

Fig. 134.—The Medial Wall of the Orbit.



The **inferior wall** or floor is directed upward and laterally and is not so large as the roof. It is formed by the orbital plate of the maxilla, the orbital process of the zygomatic, and the orbital process of the palate bone. At its medial angle it presents the **naso-lacrimal canal**, and near this, a depression for the origin of the *inferior oblique* muscle. It is marked near the middle by a furrow for the infra-orbital artery and the second division of the fifth nerve, terminating anteriorly in the infra-orbital canal, through which the nerve and artery emerge on the face. Near the commencement of the canal a narrow passage, the anterior alveolar canal, runs forward and downward in the anterior wall of the antrum, transmitting nerves and vessels to the incisor and canine teeth.

The **lateral wall**, directed forward and medially, is formed by the orbital surface of the great wing of the sphenoid, and the zygomatic. Between it and the roof, near the apex, is the **superior orbital** (sphenoidal) **fissure**, by means of which the third, fourth, ophthalmic division of the fifth, and sixth nerves enter the orbit from the cranial cavity; it also transmits some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery, recurrent branches of the lacrimal artery, and an ophthalmic vein. The lower margin of the fissure presents near the middle a small tubercle, from which the inferior head of the *lateral rectus* muscle arises. Between the lateral wall and the floor, near the apex, is the **inferior orbital** (spheno-maxillary) **fissure**, through which the second division of the fifth and the infra-orbital vessels pass from the pterygo-palatine fossa to enter the infra-orbital groove. At the anterior margin of the fissure the sphenoid occasionally articulates with the maxilla, but

the two are usually separated by the orbital plate of the zygomatic, and on the latter are seen the orifices of the zygomatico-temporal and zygomatico-facial canals, which traverse the zygomatic bone. The commencement of the zygomatico-temporal canal is sometimes seen in the spheno-zygomatic suture connecting the sphenoid and zygomatic bones.

The **medial wall,** narrow and nearly vertical, is formed from before backward by the frontal process of the maxilla, the lacrimal, the lamina papyracea of the ethmoid, and the body of the sphenoid. At the junction of the medial wall with the roof, and in the suture between the ethmoid and frontal, are seen the orifices of the **anterior** and **posterior ethmoidal canals,** the anterior, transmitting the anterior ethmoidal vessels and nerve; and the posterior, the posterior vessels and nerve. Anteriorly is the **lacrimal groove** for the lacrimal sac, and behind this the **lacrimal crest,** from which the *tensor tarsi* arises. The medial wall, which is the smallest of the four, is traversed by three vertical sutures:—one between the frontal process of the maxilla and the lacrimal, a second between lacrimal and lamina papyracea, and a third between the lamina papyracea and the sphenoid. Occasionally the **sphenoidal concha** appears in the orbit between the ethmoid and the body of the sphenoid.

The **apex** of each orbit corresponds to the **optic foramen,** a circular orifice which transmits the optic nerve and ophthalmic artery. The base or circumference is quadrilateral in form and is bounded by the frontal bone above, the frontal process of the maxilla and the medial angular process of the frontal on the medial side, the zygomatic bone and the zygomatic process of the frontal on the lateral side, and by the zygomatic and the body of the maxilla below. The following points may also be noted:—The suture between the zygomatic process of the frontal bone and the zygomatic; the supra-orbital notch (sometimes a complete foramen); the suture between the frontal bone and the frontal process of the maxilla; and in the lower segment, the zygomatico-maxillary suture.

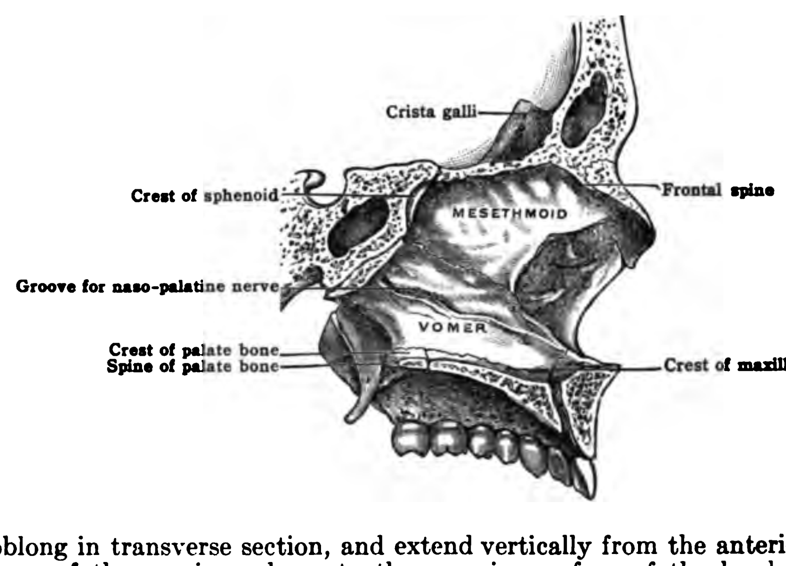
The orbit communicates with the cranial cavity by the optic foramen and superior orbital fissure; with the nasal fossa, by means of the naso-lacrimal canal; with the zygomatic and pterygo-palatine fossæ, by the inferior orbital fissure. In addition to these large openings, the orbit has five other foramina—the infra-orbital, zygomatico-orbital, and the anterior and posterior ethmoidal canals—opening into it or leading from it.

The following **muscles** arise within the **orbit**:—the *four recti*, the *superior oblique*, and *levator palpebræ superioris*, near the apex; the *inferior oblique* on the floor of the orbit lateral to the naso-lacrimal canal; and the *tensor tarsi* from the lacrimal crest. The margins of the inferior orbital fissure give attachment to the *orbitalis* muscle.

THE NASAL FOSSÆ

The **nasal fossæ** (figs. 135, 136) are two irregular cavities situated on each side of a median vertical septum. They open in front by the piriform aperture and communicate behind with the pharynx by the choanæ. They are somewhat

FIG. 135.—SECTION THROUGH THE NASAL FOSSA TO SHOW THE SEPTUM. LEFT HALF, WITH SEPTUM LOOKING TOWARD RIGHT NASAL FOSSA.



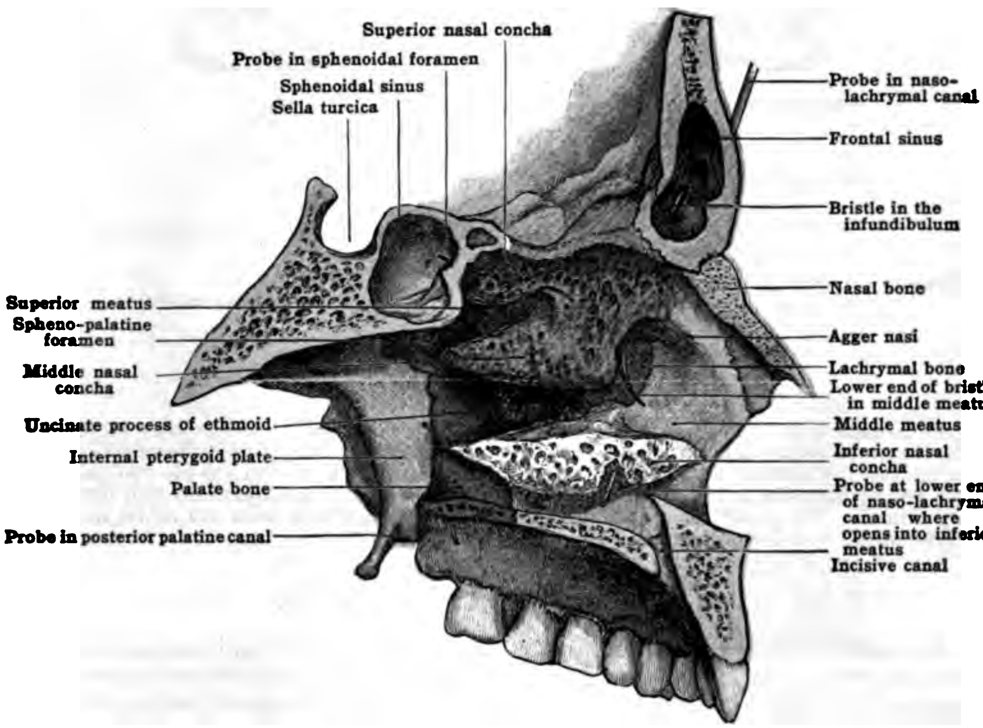
oblong in transverse section, and extend vertically from the anterior part of the base of the cranium above to the superior surface of the hard palate below. Their transverse extent is very limited, especially in the upper part. Each fossa presents for examination a roof, floor, medial and lateral walls, and communicates with the sinuses of the frontal, sphenoid, maxilla, and ethmoid bones.

The **roof** is horizontal in the middle, but sloped downward in front and behind. The anterior slope is formed by the posterior surface of the nasal bone and the nasal process of the frontal; the horizontal portion corresponds to the cribriform plate of the ethmoid and the sphenoidal concha; the posterior slope is formed by the inferior surface of the body of the sphenoid, the ala of the vomer, and a small portion of the sphenoidal process of the palate. The sphenoidal sinus opens at the upper and back part of the roof into the spheno-ethmoidal recess, above the superior meatus.

The **floor** is concave from side to side, and in the transverse diameter wider than the roof. It is formed mainly by the palatine process of the maxilla and completed posteriorly by the horizontal part of the palate bone. Near its anterior extremity, close to the septum, is the **incisive canal.**

The **septum** or medial wall is formed by the perpendicular plate of the ethmoid, the vomer, the rostrum of the sphenoid, the crest of the nasal bones, the frontal spine, and the median crest formed by the apposition of the palatine processes of the maxillæ and the horizontal parts of the palate bones. The anterior border has a triangular outline limited above by the perpendicular plate of the ethmoid and below by the vomer, and in the recent state the deficiency is filled up by the septal cartilage of the nose. The posterior border is formed by the

FIG. 136.—SECTION THROUGH THE NASAL FOSSA TO SHOW THE LATERAL WALL WITH THE MEATUSES.



pharyngeal edge of the vomer, which separates the two choanæ. The septum, which is usually deflected from the middle line to one side or the other, is occasionally perforated, and in some cases a strip of cartilage, continuous with the triangular cartilage, extends backward between the vomer and perpendicular plate of the ethmoid (*posterior* or *sphenoidal process*).

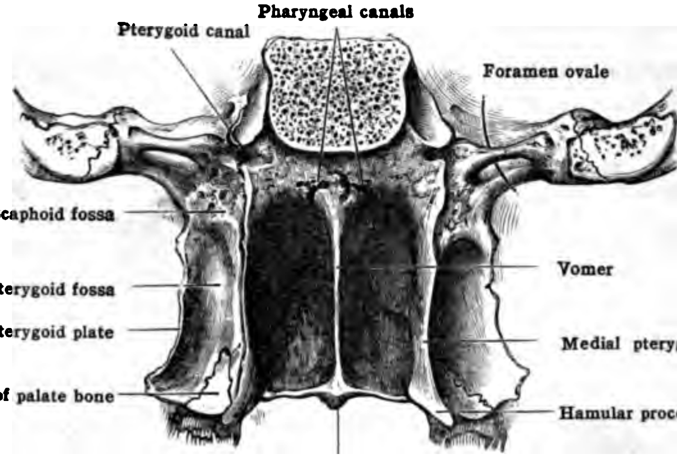
The **lateral wall** is the most extensive and the most complicated on account of the formation of the meatuses of the nose. It is formed by the frontal process and the medial surface of the maxilla, the lacrimal, the superior and inferior conchæ of the ethmoid, the inferior nasal concha, the vertical part of the palate bone, and the medial surface of the medial pterygoid plate. The three conchæ, which project medially, overhang the three recesses known as the **meatuses** of the nose. The **superior meatus**, the shortest of the three, is situated between the superior and middle nasal conchæ, and into it open the orifice of the **posterior ethmoidal cells** and the **spheno-palatine foramen.** The **middle meatus** lies between the middle and inferior conchæ. At its fore part it communicates with the frontal sinus by means of the **infundibulum,** and near the middle with the **maxillary sinus (antrum)**; the communication with the sinus is very irregular and sometimes represented by more than one opening (fig. 136). Two sets of **ethmoidal cells—the middle** and **anterior**—also open into the middle meatus, the anterior in common with the infundibulum, the middle on an elevation known as the **bulla ethmoidalis.** The **inferior meatus,** longer than either of the preceding, is situated between the inferior nasal concha and the floor of the fossa, and presents, near the anterior part, the lower orifice of the canal for the **naso-lacrimal** duct.

The **nasal fossæ** open on the face by means of the **apertura piriformis, a heart-shaped** or piriform opening whose long axis is vertical and whose broad end is below. The orifice is bounded above by the lower borders of the nasal bones, laterally by the maxillæ, inferiorly by the premaxillary portions of the maxillæ, and in the recent state the orifice is divided by the septal cartilage. Below, where the lateral margins slope inward to meet in the middle line, is the **anterior nasal spine.**

The **choanæ** (posterior nares) are bounded superiorly by the alæ of the vomer, the sphenoidal processes of the palate, and the inferior surface of the body of the sphenoid; laterally by the lateral pterygoid plates; and inferiorly by the posterior edge of the horizontal plates of the palate bones. They are separated from each other by the posterior border of the vomer.

The nasal fossæ communicate with all the more important fossæ and the air-sinuses of the skull. By means of the foramina in the roof they are in connection with the cranial cavity;

FIG. 137.—THE CHOANÆ. Veiwed from behind.



by the infundibulum each fossa is in communication with the frontal and anterior ethmoidal cells; the posterior ethmoidal cells open into the superior meatuses and the sphenoidal sinuses into the recesses above; the spheno-palatine foramina connect them with the pterygo-palatine fossæ, and by means of an irregular orifice in each lateral wall they communicate with the maxillary sinuses. The canals for the naso-lacrimal ducts connect them with the orbits, and the incisive canals with the oral cavity.

THE INTERIOR OF THE SKULL

In order to study the interior of the skull it is necessary to make sections in three directions—sagittal, coronal, and horizontal. This enables the student to examine the various points with facility, and displays the great proportion the brain cavity bears to the rest of the skull. The **sagittal section** (fig. 138) should be made slightly to one side of the median line, in order to preserve the nasal septum. The black line (fig. 138) drawn from the **basion** (anterior margin of the foramen magnum) to the **gonion** (the anterior extremity of the sphenoid) represents the **basi-cranial axis;** whilst the line drawn from the **gonion** to the **subnasal point** lies in the **basi-facial axis.** These two axes form an angle termed the **cranio-facial,** which is useful in making comparative measurements of crania. A line prolonged vertically upward from the **basion** will strike the **bregma.** This is the **basi-bregmatic** axis, and gives the greatest height of the **cranial** cavity. A line drawn from the **ophryon** to the **occipital point** indicates the greatest length of the cranium.

Near its middle, the cranial cavity is encroached upon by the petrous portion of the temporal bone on each side; the walls are channelled vertically by narrow grooves for the middle and small meningeal vessels, and toward the base and at the vertex are broader furrows for the venous sinuses.

The **coronal** section is most instructive when made in the **basi-bregmatic axis.** The section will pass through the petrous portion on each side in such a way as to traverse the external auditory passage and expose the **tympanum** and vestibule, and will also partially traverse the internal auditory **meatus.** Such

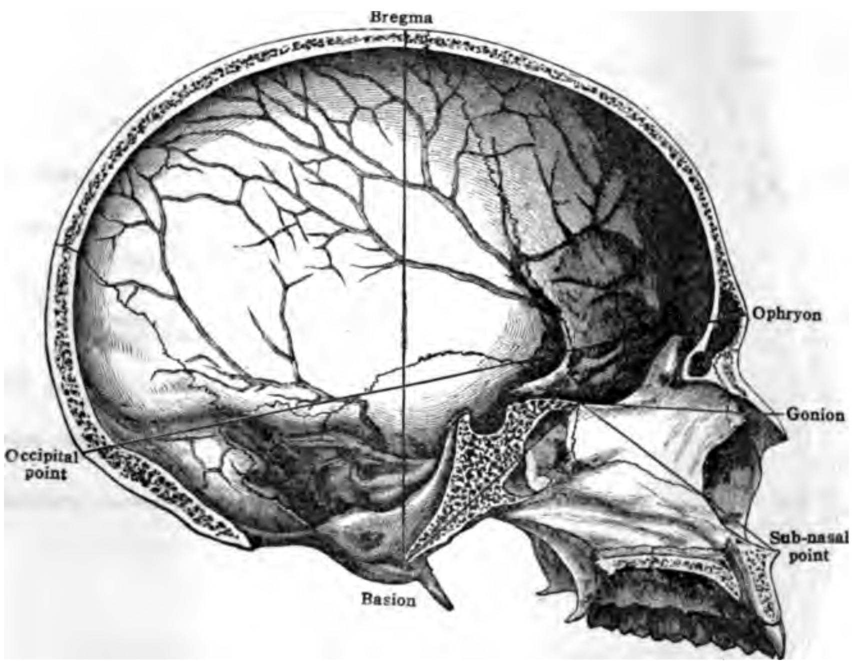
a section will divide the parietal bones slightly posterior to the parietal eminences, and a line drawn transversely across the section at the mid-point will give the greatest transverse measurement of the cranial cavity. A skull divided in this way facilitates the examination of the parts about the choanæ (posterior nares).

The **horizontal section** (figs. 139, 140) of the skull should be made through a line extending from the **ophryon** to the **occipital point,** passing laterally a few millimetres above the **pterion** on each side. It is of great advantage to study the various parts on the floor of the cranial cavity in a second skull in which the dura mater and its various processes have not been removed.

The **floor** [basis cranii interna] of the cranial cavity presents three irregular depressions termed the anterior, middle, and posterior fossæ (figs. 139 and 140).

THE ANTERIOR CRANIAL FOSSA.—The floor of this fossa is on a higher level than the rest of the cranial floor. It is formed by the horizontal plate of the frontal bone, the cribriform plate of the ethmoid, and the lesser wings of the

FIG. 138.—THE SKULL IN SAGITTAL SECTION.



sphenoid, which meet and exclude the body of the sphenoid from the anterior fossa. The free margins of the lesser wings and the anterior margin of the optic groove mark the limits of this fossa posteriorly. The central portion is depressed on each side of the crista galli, presents the numerous apertures of the cribriform plate, and takes part in the formation of the roof of the nasal fossæ; laterally, the floor of the anterior cranial fossa is convex; it forms the roof of the orbits, and is marked by irregular furrows. It supports the frontal lobes of the cerebrum. The **sutures traversing** the floor of the fossa are the fronto-ethmoidal, forming three sides of a rectangle, that portion of the transverse facial suture which traverses the roof of the orbit, and the ethmo-sphenoidal suture, the centre of which corresponds to the **gonion.** The other points of interest in the fossa are:—

A **groove** for the superior sagittal sinus.
The **foramen cæcum** which frequently transmits a small vein to the nasal cavity.
The **crista galli.**
The **ethmoidal fissure** for the anterior ethmoidal branch of the fifth nerve.
The **cranial orifice of the anterior ethmoidal canal,** transmitting the anterior ethmoidal branch of the fifth nerve, and a meningeal branch of the anterior ethmoidal artery.
The **cranial orifice of the posterior ethmoidal canal,** transmitting a meningeal branch of the posterior ethmoidal artery.
The **ethmoidal spine** of the sphenoid.
Furrows for meningeal vessels.

FIG. 139.—THE SKULL IN HORIZONTAL SECTION.

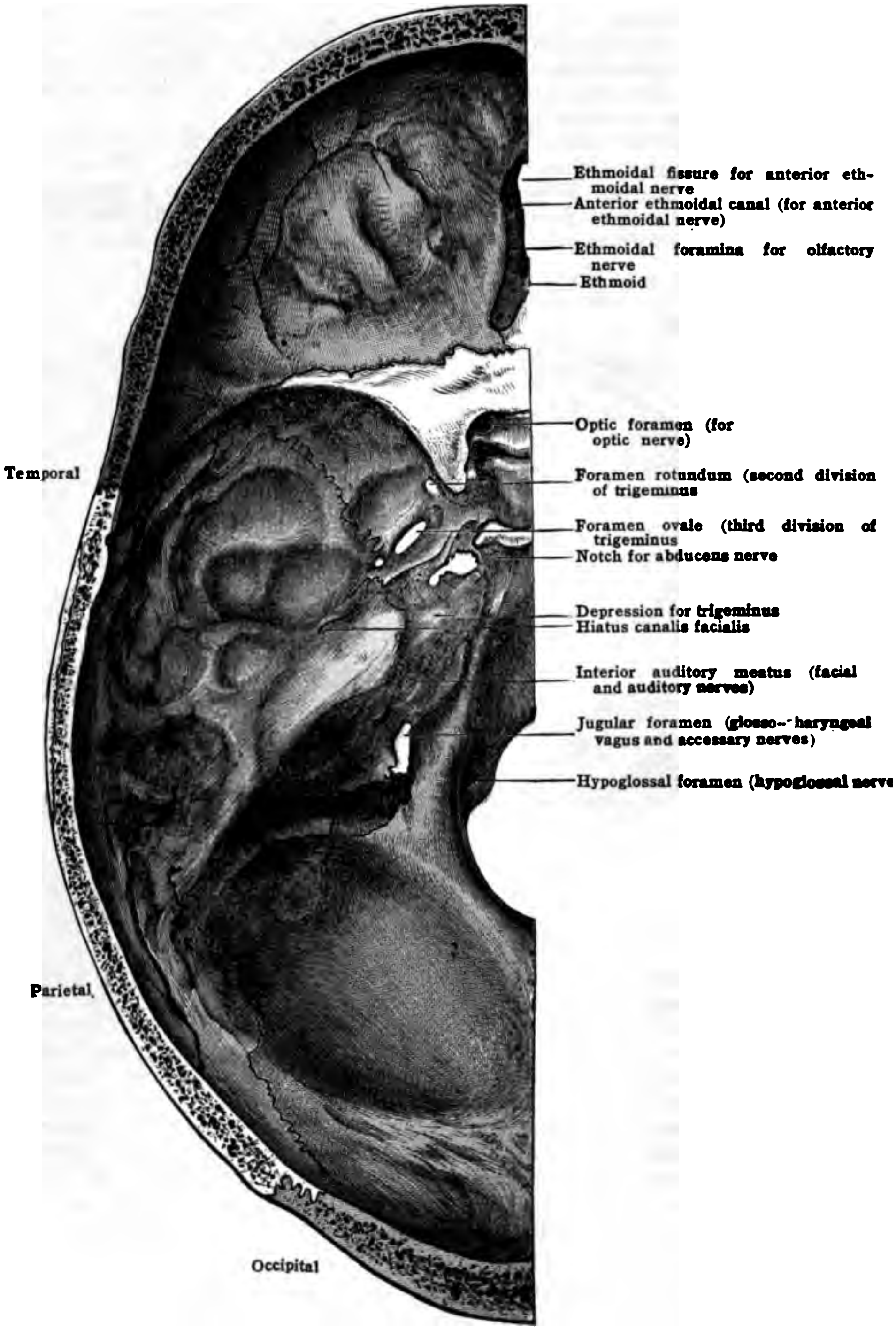
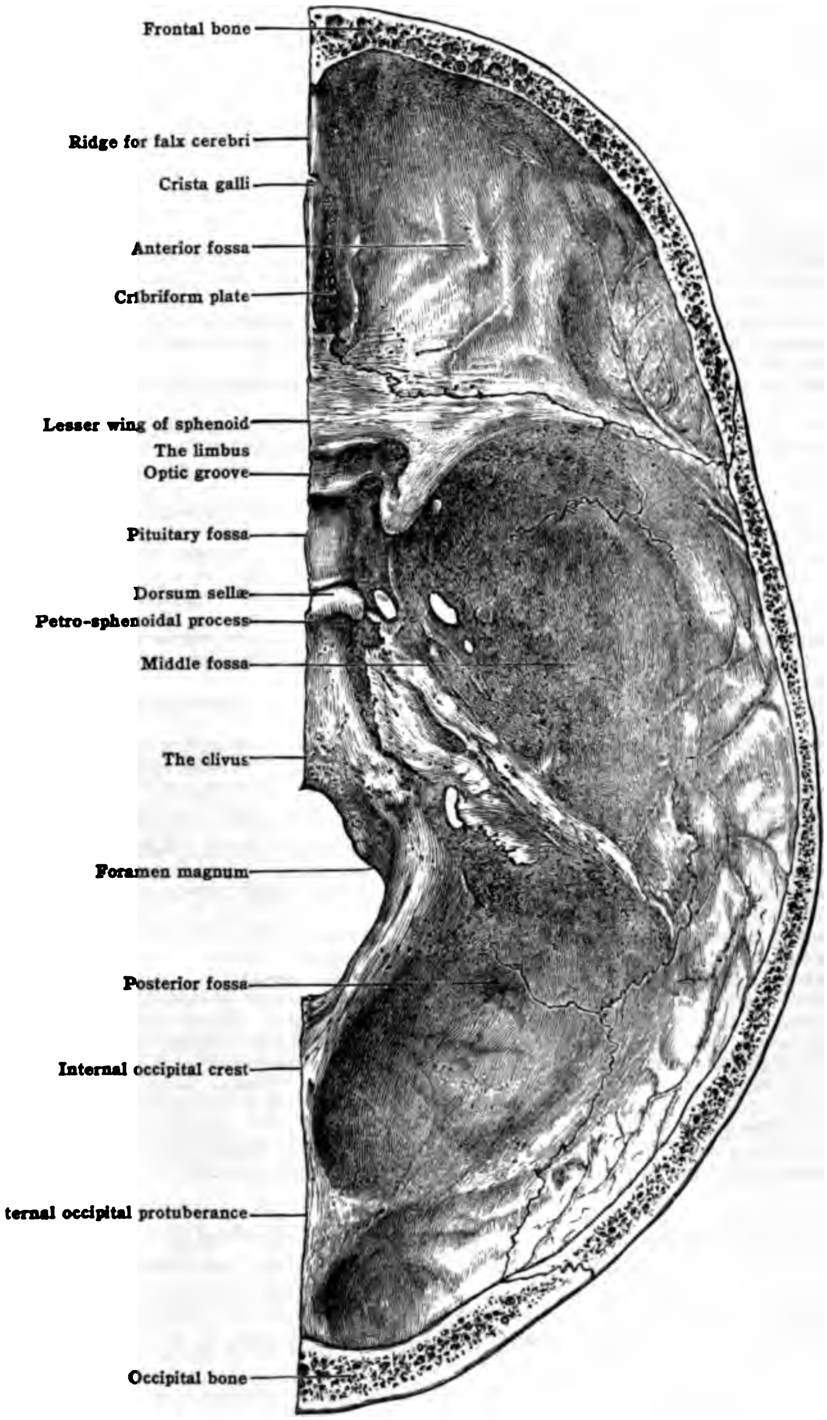


FIG. 140.—THE SKULL IN HORIZONTAL SECTION.



The Middle Cranial Fossa, situated on a lower level than the anterior, consists of a central and two lateral portions. In front it is limited by the posterior borders of the lesser wings of the sphenoid and the anterior margin of the optic groove, behind by the dorsum sellæ and the upper angle of the petrous portion of both temporal bones. Laterally it is bounded on each side by the squamous portion of the temporal, the great wing of the sphenoid, and the parietal bone, whilst the floor is formed by the body and great wings of the sphenoid and the anterior surface of the petrous portion of the temporals. It contains the following sutures:—spheno-parietal, petro-sphenoidal, squamo-sphenoidal, squamous, and a part of the transverse suture. The central portion of the fossa presents from before backward:

The **optic groove**, above and behind which is the optic chiasma.
The **optic foramen** on each side, transmitting the optic nerve and ophthalmic artery.
The **tuberculum sellæ**, indicating the line of junction of pre- and post-sphenoid elements.
The **anterior clinoid processes.**
The **fossa hypophyseos** or **sella turcica**, with the **middle clinoid processes**, and **grooves** for the internal carotid arteries. The **dorsum sellæ**, with the **posterior clinoid processes**, and notches for the sixth pair of cranial nerves.

The central portion is in direct relation with the parts of the brain within the circle of Willis.

The lateral portions are of considerable depth and marked by numerous elevations and depressions corresponding to the convolutions of the temporal lobes of the brain, and by grooves for the branches of the middle and small meningeal vessels. The following foramina are seen on each side:—

The **superior orbital** (sphenoidal) **fissure**, leading into the orbit and transmitting the third, fourth, three branches of the ophthalmic division of the fifth and sixth cranial nerves, some filaments from the cavernous plexus of the sympathetic, an ophthalmic vein, the orbital branch of the middle meningeal, and a recurrent branch of the lacrimal artery.
The **foramen rotundum**, for the passage of the second division of the fifth nerve into the pterygo-palatine fossa.
The **foramen ovale**, which transmits the third division of the fifth nerve with its motor root (mandibular nerve), the small meningeal artery, and the small superficial petrosal nerve.
The **foramen Vesalii** (not always present) for a small vein.
The **foramen spinosum**, for the middle meningeal artery and its venæ comitantes; also the N. spinosus.
The **foramen lacerum** is the irregular aperture between the body and great wing of the sphenoid, and the apex of the petrous portion of the temporal. In the recent state it is closed below by a layer of fibro-cartilage which is perforated by the Vidian nerve, a meningeal branch of the ascending pharyngeal artery, and an emissary vein. The carotid canal opens on its lateral wall and the pterygoid (Vidian) canal in front.

On the anterior surface of the petrous portion of the temporal bone are seen:—
A depression which lodges the semilunar (Gasserian) ganglion.
The **hiatus canalis facialis** for the great superficial petrosal nerve and the petrosal branch of the middle meningeal artery.
The **accessory hiatus** for the small superficial petrosal nerve.
A minute foramen for the external superficial petrosal nerve.
The **eminentia arcuata**, formed by the superior semicircular canal.

Anterior and slightly lateral to the eminentia arcuata the bone is exceedingly thin and translucent, forming the roof of the tympanum (tegmen tympani). When the dura mater is *in situ*, the depression lodging the semilunar ganglion is converted into a foramen, traversed by the fifth nerve, and in the same way the notch on the side of the dorsum sellæ is converted into a foramen for the sixth nerve. In many skulls the middle clinoid process is prolonged toward the anterior clinoid process, with which it may be joined to complete a foramen for the internal carotid artery. The grooves for the middle meningeal vessels are sometimes converted into canals or tunnels for a short distance, especially in old skulls. The bones most deeply marked are the squamous portion of temporal, the great wing of the sphenoid, and the parietal.

The Posterior Cranial Fossa is the deepest and largest of the series. It is bounded in front by the dorsum sellæ of the sphenoid and on each side by the superior border of the petrosal, and the mastoid portion of the temporal bone, the posterior inferior angle of the parietal, and the groove on the occipital bone for the transverse sinus; each of the bones mentioned takes part in the formation of its floor.

In the recent state the fossa lodges the cerebellum, pons, and medulla, and is roofed in by the tentorium cerebelli, a tent-like process of the dura mater attached to the ridges limiting the fossa above. It communicates with the general cranial cavity by means of the **foramen ovale of Pacchionius**, a large opening bounded in front by the clivus (basilar groove) and behind by the anterior free edge of the tentorium.

The **posterior fossa** is marked by several sutures, viz., petro-occipital, occipito-mastoid, parieto-mastoid, and in young skulls the basilar (occipito-sphenoidal). In addition, the following points may be noted:—

The **clivus**, extending from the dorsum sellæ to the anterior margin of the foramen magnum, and in relation with the basilar artery, the pons, the medulla, the sixth nerves, and the basilar sinus.

The **foramen magnum**, occupied in the recent state by the lower end of the medulla oblongata and its membranes, the vertebral, anterior spinal and posterior spinal arteries, the accessory (eleventh) cranial nerves, and the tectorial membrane.

The **hypoglossal canal** (foramen), sometimes divided by a spicule of bone into two divisions, for the two parts of the hypoglossal nerve and a meningeal branch of the ascending pharyngeal artery.

The **internal occipital crest**, behind the foramen magnum, for the attachment of the falx cerebelli. It sometimes presents a depression known as the **vermiform fossa.**

The **internal auditory meatus**, for the seventh and eighth cranial nerves, the pars intermedia, and the internal auditory vessels.

The **jugular foramen** (foramen lacerum posterius), somewhat pyriform in shape, and divisible into three compartments. The anterior division, placed somewhat medially, transmits the inferior petrosal sinus and is sometimes completely separated by an intra-jugular process of bone; the middle division transmits three cranial nerves, the ninth, tenth, and eleventh; and, in the posterior division, placed somewhat laterally, the transverse sinus becomes continuous with the internal jugular vein. A meningeal branch of the ascending pharyngeal or occipital artery enters the cranium through this division of the foramen.

The termination of the groove for the transverse sinus with the internal orifice of the **mastoid foramen.**

The **aquæductus vestibuli** and the **fossa subarcuata**, on the posterior surface of the petrous portion of the temporal.

The cranium of an average European has a *capacity* of 1450 c.c. The *circumference*, taken in a plane passing through the ophryon in front, the occipital point behind, and the pterion at the side, is 52 cm. The *length* from the ophryon to the occipital point is 17 cm., and the width between the parietals at the level of the zygomata is 12.5 cm. The proportion of the greatest width to the length is known as the *cephalic index*, i. e., index of breadth. A skull with an average cephalic index is *mesaticephalic*. When the index is above the average, it is *brachycephalic* (short and broad), and when below the average, *dolichocephalic* (long and narrow). The *height* from the basion to the bregma is nearly the same as the width at the level of the zygomata. The cranio-facial angle is about 96°.

THE MORPHOLOGY OF THE SKULL

In man the skull during development passes through three stages. At first the brain vesicles are enclosed in a sac of indifferent tissue which ultimately becomes tough and fibrous to form the **membranous cranium.** This, in turn, is partly converted into the membrane or roof bones of the cranium, whilst the remainder is represented in the adult by the **dura mater.** At the sides and base of the membranous cranium, however, cartilage is deposited, **chondro-cranium,** in which, as well as in the membranous tracts, osseous tissue appears in due course. Eventually, as **osseous box** is formed, consisting of membrane bones and cartilage bones intricately interwoven.

A study of the skull in the chondral stage is very instructive. It consists of two parts: (1) The skull proper and (2) the appendicular elements.

(1) The **skull proper** consists of three regions:—

(*a*) The **notochordal** region, which ultimately gives rise to the chief parts of the occipital bone and a part of the sphenoid. It is named notochordal because the notochord runs in it as far as the anterior extremity, i. e., the level of the fossa hypophyseos (sella turcica.)

(*b*) Anterior to the notochordal is the **trabecular region,** from which the remainder of the sphenoid is developed.

(*c*) The most anterior part of the prechordal portion of the base is the **ethmo-vomerine region,** from which the nasal septum and its cartilages arise. These three parts continue forward the line of the vertebral axis, and constitute a *cranio-facial axis* terminating, in front, in the premaxillæ. Finally, wedged in on each side, between the notochordal and trabecular regions, is the complicated **periotic capsule.**

The **chondro-cranium** at the third month presents the following parts. Seen from above, the cartilage extends from the cranial base to a spot midway between the base and the vertex, shading off indefinitely on the membranous wall. The oval masses on each side are the **periotic cartilages,** in which the fossæ subarcuatæ are conspicuous objects. Each periotic cartilage is joined to the sphenoid by a strip, termed the **sphenotic cartilage,** which usually persists in the adult skull. The cartilage for the orbito-sphenoid (the small wing) is co-extensive with the ali-sphenoid, and forms part of the lateral wall of the skull. The snout-like appearance of the anterior part of the skull is caused by the **fronto-nasal** plate. On each side of the ethmo-vomerine plate, near its anterior termination, are two small concave pieces of cartilage for Jacobson's organs. They are sometimes referred to as the ploughshare cartilages, owing to their shape. Further details are given in fig. 141.

(2) The **appendicular elements** of the skull are a number of cartilaginous rods surrounding the visceral cavity—i. e., nose, mouth, and pharynx—which undergo a remarkable metamorphosis, and are represented in the adult by the *ear bones*, the *styloid process*, and the *hyoid bone*.

FIG. 141.—MODEL OF THE CHONDRO-CRANIUM OF A HUMAN FŒTUS 8 CM. IN LENGTH. Cartilage in Blue. Viewed from Above. (After O. Hertwig.)

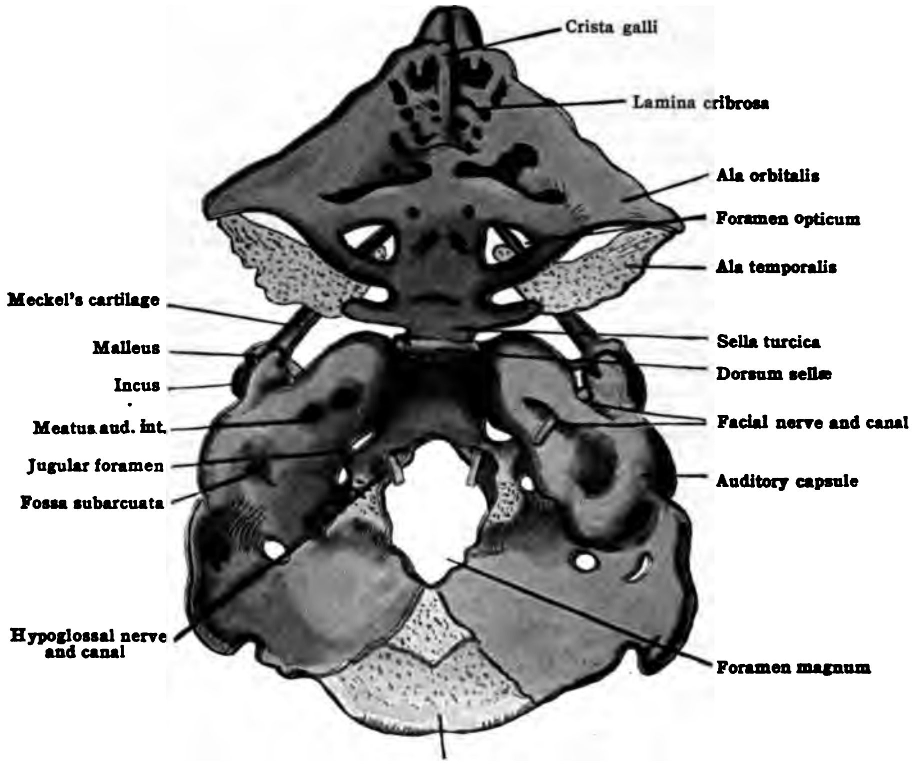
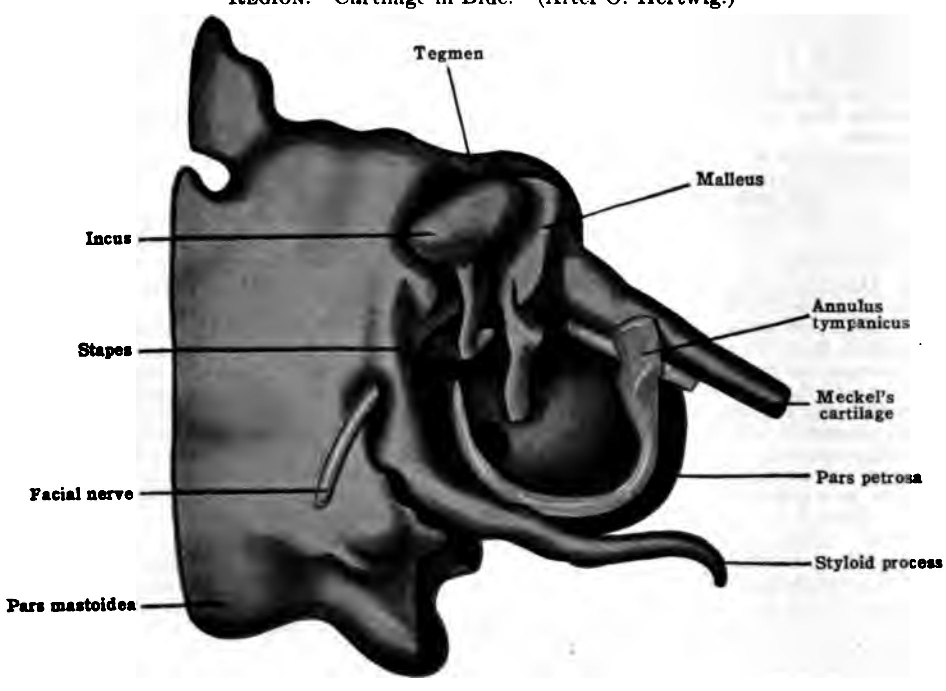


FIG. 142.—AN ENLARGED PORTION OF THE SAME MODEL OF THE CHONDRO-CRANIUM AS SHOWN IN FIG. 141. VIEWED FROM THE RIGHT SIDE, SHOWING THE SKELETON OF THE AUDITORY REGION. Cartilage in Blue. (After O. Hertwig.)



Metamorphosis of the Branchial or Visceral Bars

These rods of cartilage are named, f om before backward, the **mandibular, hyoid,** and **thyreoid** bars. They may with care be easily dissected in the fœtus between the third and fourth months. Their metamorphosis is as follows:—

The two extremities of the **mandibular bar** (cartilago Meckelii) ossify; the distal end ultimately forms a portion of the mandible near to the symphysis (see p. 98); the proximal end ossifies as the **malleus** and **incus.** The intermediate portion disappears; the only vestige is a band of fibrous tissue, the spheno-mandibular ligament, extending from the spine of the sphenoid to the spine of the mandible.

In the connective tissue surrounding the bar there appear, however, ossifications, one of which invests the bar to form the dentary plate; while a second, situated more proximally, forms the tympanic bone.

The **hyoid bar** fuses distally with the thyreoid bar, and forms part of the **hyoid bone.** Its proximal end becomes the **stapes,** the **tympano-hyal** portion of the styloid process (fused with the petro-mastoid), and the **stylo-hyal** or free portion of the process. The succeeding portion **(epi-hyal segment)** is represented in the adult by the stylo-hyoid ligament, and the lowest segment, or **cerato-hyal,** by the small cornu of the hyoid.

The **thyreoid bar** forms the great cornu of the hyoïd bone **(thyreo-hyal).** The body of the hyoid **(basi-hyal)** is regarded as representing the fused ventral ends of the hyoidean and thyreoidean arches.

In addition to these structures ossifications occur in the connective tissue of the maxillary process, a structure which may be regarded as forming the anterior part of the first branchial arch, and in the fronto-nasal process. The ossifications in the maxillary process give rise to the pterygoid (medial pterygoid process of the sphenoid), the palate, the maxilla, and the zygomatic, while that in the fronto-nasal process forms the premaxilla.

The bony elements of the head may therefore be arranged, according to their origin, in the following table:—

I. Basilar Bones Developed in the Cartilaginous Cranium

Basi-occipital............	Basilar portion of the occipital bone.
Exoccipitals..	Condylar parts of the occipital bone.
Supra-occipital...........	Lower part of the squamous portion of the occipital.
Basi-sphenoid } **Pre-sphenoid** }	Constituting the body of the sphenoid.
Ali-sphenoids............	Greater wings and lateral pterygoid plates.
Orbito-sphenoids	Lesser wings.
Petro-mastoids...........	Petrous and mastoid portions (excepting post-auditory processes) of the temporal bones.

II. Roof Bones Developed in the Membranous Cranium

Squamosals..............	Squamous portions of temporals.
Parietals.................	The two parietal bones.
Frontals..................	United to form a median frontal bone.
Interparietal.............	Upper part of squamous portion of occipital.
Epipterics................	The epipteric bones.

III. Bones of the Nasal Region

Mesethmoid.............	Vertical plate of ethmoid developed in the cartilage of the cranio-facial axis.
Ethmo-turbinals..........	Superior and inferior conchal processes of ethmoid.
Maxillo-turbinals.........	The inferior nasal conchæ.
Cribriform lamina........	Cribriform plate of ethmoid.
These elements are developed in the cartilage of the lateral nasal process.	
Sphenoidal turbinals......	Sphenoidal conchæ. These are derivatives of the ethmo-turbinals.
Lacrimals...............	The lacrimal bones } Developed in the membrane over the lateral nasal process.
Nasals..................	The nasal bones }
Vomer..................	The vomer. Ossified in the membrane investing the cartilage of the cranio-facial axis.

IV. Facial Bones

Maxillæ.................	The maxillæ........ } Developed in the connective tissue of the maxillary process.
Zygomatics..............	The zygomatic bones }
Premaxillæ..............	The incisor parts of the maxillæ. Formed at the anterior extremity of the cranio-facial axis in the tissue of the fronto-nasal process (proc. globulares).

V. APPENDICULAR ELEMENTS (BONES OF THE VISCERAL ARCHES)

(A) *Cartilaginous*

Malleus, Incus, and Stapes	The ossicula auditus.
Mento-Meckelian portion of the lower jaw	Small part on either side near to the symphysis menti.
Tympano-hyals and Stylo-hyals	Styloid processes of the temporal bones.
Epihyals	Stylo-hyoid ligaments.
Cerato-hyals	Lesser cornua of hyoid bone.
Thyreo-hyals	Greater cornua of hyoid bone.
Basi-hyals	Body of hyoid bone.

(B) *Membranous*

Mandible	The lower jaw excluding a small portion near symphysis.
Tympanics	The tympanic plates.
Pterygoids	The medial pterygoid plates.
Palatals	The palate bones.

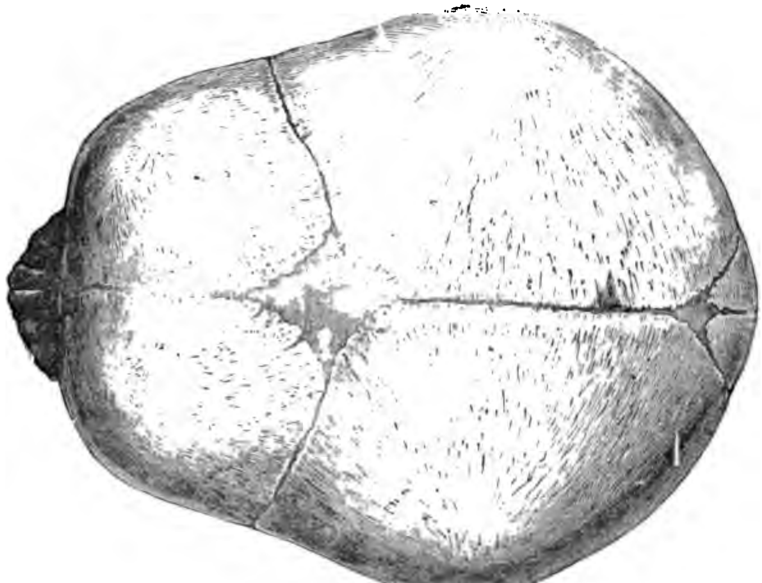
The Skull at Birth

The skull at birth presents, when compared with the adult skull, several important and interesting features. Its peculiarities may be considered under three headings:—The peculiarities of the fœtal skull as a whole; the construction of the individual bones; the remnants of the chondral skull.

(1) *The General Characters of the Fœtal Skull*

The most striking features of the skull at birth are, its relatively large size in comparison with the body, and the predominance of the cranial over the facial portion of the skull (8 to 1); the latter is, in fact, very small.

FIG. 143.—THE CRANIUM AT BIRTH. (Viewed from above.)

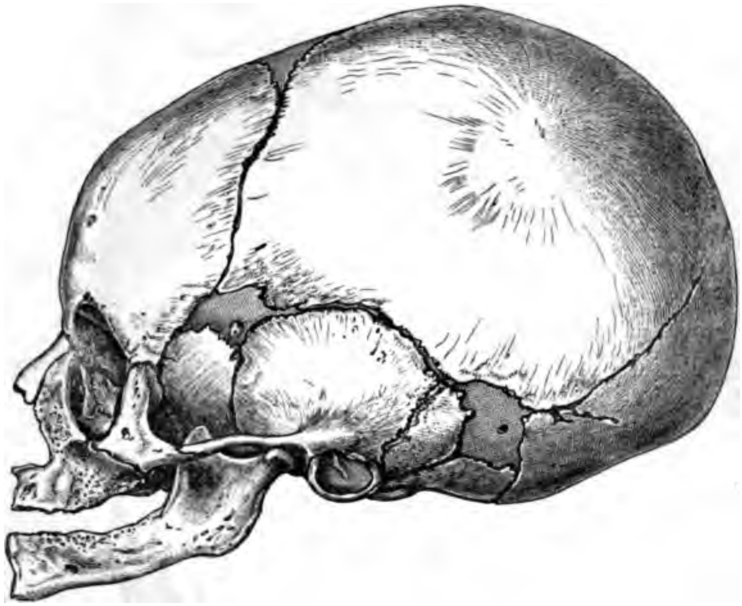


The frontal and parietal eminences are large and conspicuous; the sutures are absent; the adjacent margins of the bones of the vault are separated by septa of fibrous tissue continuous with the dura mater internally and the pericranium externally; hence it is difficult to separate the roof bones from the underlying dura mater, each being lodged, as it were, in a dense membranous sac. The bones of the vault consist of a single layer without any diploë, and their cranial surfaces present no digital impressions. Six membranous spaces exist, named fontanelles: two are median, the frontal [fonticulus frontalis; major] being anterior and the occipital [fonticulus occipitalis; minor] posterior. Two exist on each side, termed anterior [fonticulus sphenoidalis] and posterior [fonticulus mastoideus] lateral fontanelles. Each angle of the parietal bones is in relation with a fontanelle. The anterior fontanelle is lozenge-shaped, the posterior triangular. The lateral fontanelles are irregular in outline. The lateral fontanelles close soon after birth; the occipital fontanelle closes in the first year, and the frontal during the second year.

Turning to the base of the skull, the most striking points are the absence of the mastoid processes, and the large angle which the pterygoid plates form with the skull-base, whereas in the adult it is almost a right angle. The base of the skull is relatively short, and the lower border of the mental symphysis is on a level with the occipital condyles.

The facial skeleton is relatively small in consequence of the small size of the nasal fossæ, the small size of the maxillary sinus, and the rudimentary condition of the alveolar borders

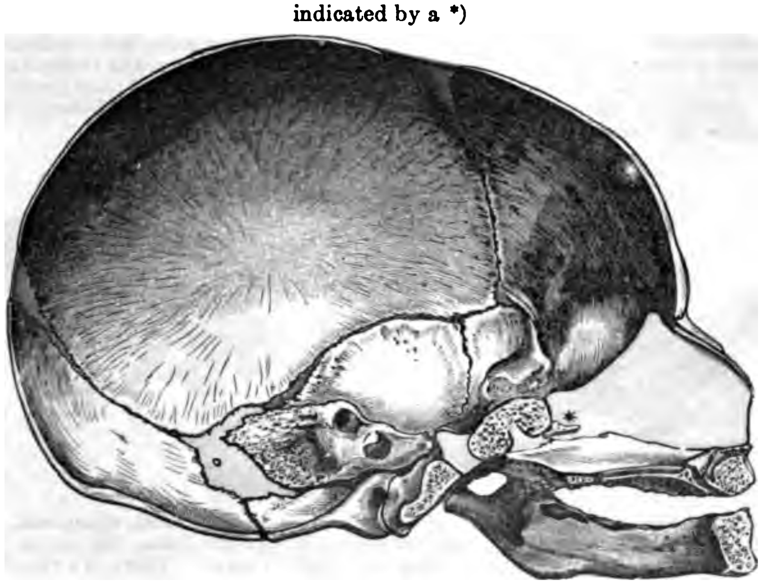
FIG. 144.—THE CRANIUM AT BIRTH. (Lateral view.)



of the maxillæ and mandible; the nasal fossæ are as wide as they are high, and are almost filled with the conchæ.

Growth takes place rapidly in the first seven years after birth. There is a second period of rapid growth at puberty, when the air sinuses develop, and this affects especially the face and frontal portion of the cranium.

FIG. 145.—THE CRANIUM AT BIRTH IN SAGITTAL SECTION. (Sphenoidal concha indicated by a *)



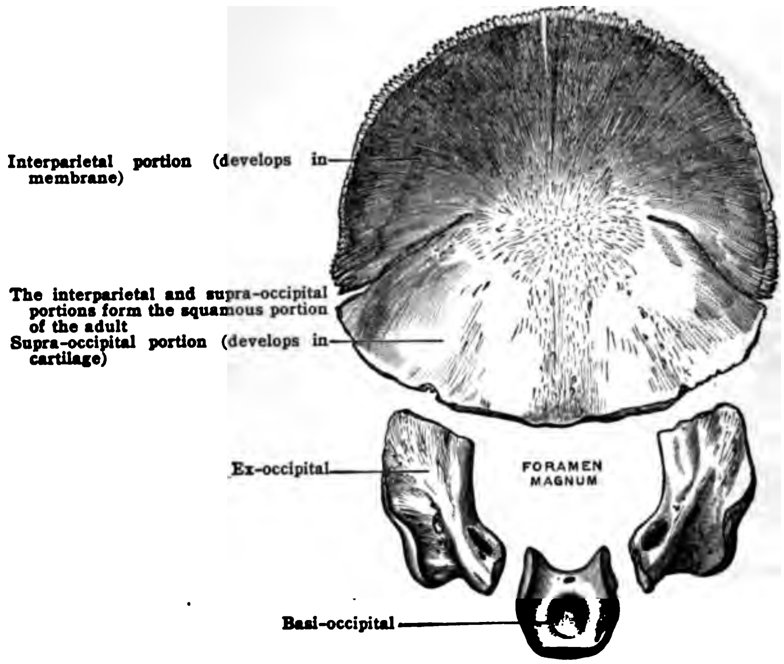
(2) *The Peculiarity of Individual Bones at Birth*

The **occipital bone** consists of four distinct parts, which have already been described. Compared with the adult bone, the following are the most important points of distinction:—There is no **pharyngeal tubercle** or **jugular** process; the squamous portion presents two deep **fissures separating the interparietal** from the supra-occipital portion and extending medially

as far as the occipital protuberance. The grooves for the transverse (lateral) sinuses are absent.

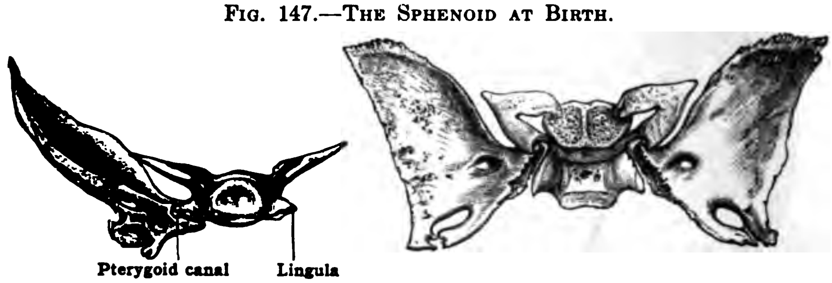
The **sphenoid** in a macerated fœtal skull falls into three pieces: (1) united **pre- and post-sphenoids, orbito-sphenoids,** and **lingulæ,** and (2 and 3) the **ali-sphenoids.** The **pre-sphenoid** is quite solid and connected with the ethmo-vomerine cartilage, and presents no **traces** of the air sinuses which occupy this part in the adult skull. The pre-sphenoid by its upper surface forms part of the anterior cranial fossa, from which it is subsequently excluded by the growth of the orbito-sphenoids. The optic foramina are large and triangular in shape. The **lingulæ**

Fig. 146.—The Occipital at Birth.



stand out from the basi-sphenoid as two lateral buttresses, and at the tuberculum sellæ is the **basi-pharyngeal canal,** which in the recent bone is occupied by fibrous tissue. The **dorsum sellæ** is still cartilaginous. The **ali-sphenoids** with the pterygoid processes are separated from the rest of the bone by cartilage. The foramen rotundum is complete, but the future foramen ovale is merely a deep notch in the posterior border of the great wing, and there is no foramen spinosum. The pterygoid processes are short, and each medial pterygoid plate presents a broad surface for articulation with the lingula. The **pterygoid canal** is a groove between the medial pterygoid plate, the lingula, and great wing.

Fig. 147.—The Sphenoid at Birth.



The **temporal bone** at birth consists of three elements, the **petrosal, squamosal,** and **tympanic.** The **petrosal** presents a large and conspicuous floccular fossa; the **hiatus Fallopii** is a shallow bay lodging the geniculate ganglion of the facial nerve. There is a relatively large mastoid antrum, but no mastoid process. The styloid process is unossified, but the **tympano-hyal** may be detected as a minute rounded nodule of bone near the stylo-mastoid foramen.

The **squamosal** has a very shallow mandibular fossa and a relatively large post-glenoid tubercle. The posterior part of the inferior border is prolonged downward into an uncinate process (*post-auditory process*) which closes the mastoid antrum laterally.

The **tympanic** bone or annulus is a delicate, horseshoe-shaped ossicle, attached by its anterior and posterior extremities to the inferior border of the squamosal.

The **ear-bones** are chiefly of interest from their size, for they are as large at birth as in the adult. The anterior process (Folian process) may be 2 cm. in length.

FIG 148.—THE TEMPORAL BONE AT BIRTH.

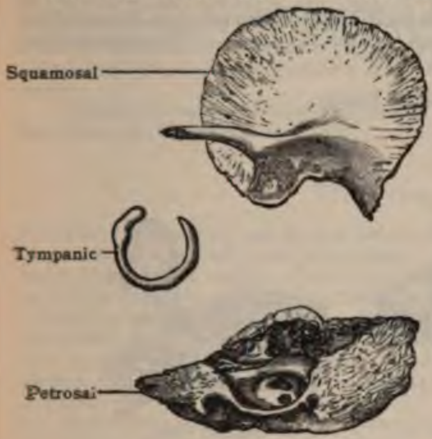


FIG. 149.—TEMPORAL BONE AT BIRTH. (Medial view.)

FIG. 150.—THE TEMPORAL BONE AT BIRTH. (Lateral view.)

The **frontal** consists of two bones separated by a median vertical (metopic) suture. The frontal eminence is very pronounced, but the superciliary arches and frontal sinuses are wanting. The frontal spine, which later becomes one of the most conspicuous features of this bone, is absent. There is no temporal line.

FIG. 151.—THE FRONTAL BONE AT BIRTH.

The **parietal** is simply a quadrilateral lamina of bone, concave on its inner and convex on the outer surface. The parietal eminence, which indicates the spot in which the ossification of the bone commenced, is large and prominent. The grooves for blood-sinuses, as in other cranial

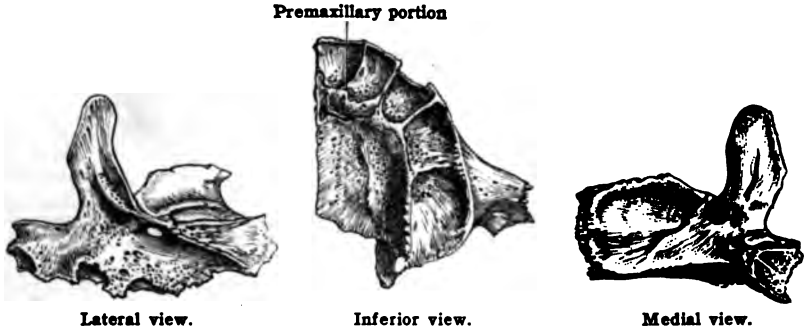
bones, are absent. Each angle of the parietal is in relation with a fontanelle. As in the adult, the anterior inferior angle of the bone is prolonged downward toward the ali-sphenoid.

The **ethmoid** consists of two lateral portions separated by the still cartilaginous ethmo-vomerine plate. The ethmoid cells are represented by shallow depressions, and the uncinate process is undeveloped.

The **sphenoidal conchæ** are two small triangular pieces of bone lying in the perichondrium on each side of the ethmo-vomerine plate near its junction with the pre-sphenoid. (Indicated by the * in fig. 145.)

The **maxilla** presents the following characters:—The incisive suture is visible on the palatine aspect of the bone. The alveolar border presents five sockets for teeth. The infra-orbital

FIG. 152.—THE MAXILLA AT BIRTH.



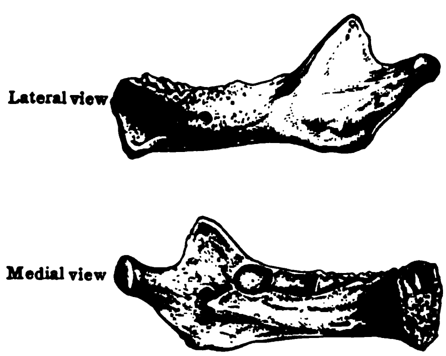
foramen communicates with the floor of the orbit by a deep fissure; this fissure sometimes persists in the adult. The sinus is a shallow depression.

The **mandible** at birth consists of two halves united by fibrous tissue in the line of the future symphysis. Each half is a bony trough lodging teeth. The trough is divided by thin osseous partitions into five compartments: of these, the fifth is the largest, and is often subdivided by a ridge of bone. The floor is traversed by a furrow as far forward as the fourth socket (that for the first milk molar), where it turns outward at the mental foramen. This furrow lodges the inferior alveolar nerve and artery, which enter by the large mandibular foramen. The condyle is on a level with the upper border of the anterior extremity of the bone.

The **palate bones** differ mainly from those in the adult in that the vertical and horizontal plates are of the same length; thus the nasal fossæ in the fœtus are as wide as they are high, whereas in the adult the height of each nasal fossa greatly exceeds the width.

Concerning the remaining bones little need be said. The vomer is a delicate trough of bone for the reception of the inferior border of the ethmo-vomerine plate; its inferior border,

FIG. 153.—THE MANDIBLE AT BIRTH.



which rests upon the hard palate, is broad, and the bone presents quite a different appearance from that in the adult. The **nasal bones** are short and broad; the **zygomatics** and **inferior conchæ** are relatively very large; and the **lacrimals** are thin, frail, and delicate lamellæ.

The **hyoid** consists of five parts. There is a median nucleus for the basi-hyal, and one on each side for the greater cornua (thyreo-hyals). The lesser cornua are cartilaginous.

(3) *Remnants of the Cartilaginous Cranium*

It has already been pointed out that at an early date the base of the skull and the face are represented by hyaline cartilage, which for the most part is replaced by bone before birth. Even at birth remnants of this primitive chondral skull are abundant. In the cranium, cartilaginous tracts exist between the various portions of the occipital bone, as well as at the line of

junction of the occipital with the petrosal and sphenoid. The dorsum sellæ is entirely cartilaginous at birth, and the last portion of this cartilage disappears with the ankylosis of the basi-occipital and basi-sphenoid about the twentieth year. A strip of cartilage unites the alisphenoids with the lingulæ, and for at least a year after birth this cartilage is continuous with that which throughout life occupies the foramen lacerum. A strip of cartilage exists along the posterior border of the orbito-sphenoid, and not unfrequently extends lateralward to the pterion. In the adult skull it is replaced by ligamentous tissue.

The ethmo-vomerine plate is entirely cartilaginous, and near the end of the nose supports the lateral nasal cartilages, remnants of the fronto-nasal plate. The fate of the ethmo-vomerine plate is instructive. The upper part is ossified to form the mesethmoid; the lower part atrophies from the pressure exerted by the vomer; the anterior end remains as the septal cartilage. The lateral snout-like extremities of the fronto-nasal plate persist as the lateral cartilages of the nose.

Among the appendicular elements of the skull, the styloid process and a large portion of the hyoid are cartilaginous at birth.

The Nerve-foramina of the Skull

The various foramina and canals in the skull which give passage to nerves may be arranged in two groups, **primary** and **secondary**. **Primary** foramina indicate the spots where the nerves leave the general cavity of the dura mater, and as this membrane indicates the limit of the primitive cranium, a cranial nerve, in a morphological sense, becomes extra-cranial at the point where it pierces this membrane. In consequence of the complicated and extraordinary modifications the vertebrate skull has undergone, many nerves traverse, in the adult skull, bony tunnels and canals which are not represented in the less complex skulls of low vertebrates, such as sharks and rays. To such foramina and canals the terms **secondary** or **adventitious** may be applied.

Nerve-foramina are further interesting in that they occupy sutures, or indicate the points of union of two or more ossific centres. To this rule the foramen rotundum is the only exception in the human skull.

The Primary Foramina

1. **Foramen magnum.**—This is bounded by four distinct centres, the supra-, basi-, and two ex-occipitals. It transmits the accessory (eleventh) pair of cranial nerves, the vertebral arteries and their anterior and posterior spinal branches, the medulla oblongata and its membranes, and the membrana tectoria.

2. **The hypoglossal.**—At birth this is a deep notch in the anterior extremity of the ex-occipital, and becomes a complete foramen when the basi- and ex-occipitals fuse. Occasionally it may be complete in the ex-occipital, but it indicates accurately the line of union of these two elements of the occipital bone. It transmits the hypoglossal nerve, the meningeal branch of the ascending pharyngeal artery, and its venæ comitantes.

3. **Jugular foramen.**—This occupies the petro-occipital suture, and is formed by the basi- and ex-occipital in conjunction with the petrosal. It transmits the glosso-pharyngeal, vagus, and accessory nerves, a meningeal branch of the ascending pharyngeal artery, and receives the transverse and inferior petrosal sinuses.

4. **Auditory.**—This marks the point of confluence of the groups of centres termed pro-otic and opisthotic. It transmits the facial and auditory nerves, the pars intermedia, and the auditory twig of the basilar artery.

5. **Trigeminal.**—This is only a foramen when the dura mater is present in the skull. It is a notch at the apex of the petrosal converted into a foramen by the tentorium. The main trunk of the trigeminal nerve, with the small motor root (masticator nerve), traverses it.

6. **Petro-sphenoidal.**—This is a notch between the side of the dorsum sellæ and apex of the petrosal which becomes converted into a foramen by dura mater.

7. **Optic.**—This foramen is formed by the confluence of the orbito- and pre-sphenoidal centres. It opens into the orbit and transmits the optic nerve and ophthalmic artery.

The Secondary Nerve-foramina

Foramina transmitting the various subdivisions of the trigeminal nerve.—The primary foramen of exit for the trigeminal nerve is formed partly of bone and partly of membrane at the apex of the petrosal. The three divisions of the nerve issue through secondary foramina.

(*a*) The **superior orbital** (sphenoidal) fissure is an elongated chink, bounded above by the orbital wing and below by the great wing of the sphenoid, medially by the body of the sphenoid, and laterally by the frontal. It opens into the orbit, and transmits the third, fourth, first (ophthalmic) division of the trigeminal and abducens nerves, also the ophthalmic vein or veins.

(*b*) The **foramen rotundum** is the only exception to the rule relating to the formation of nerve-foramina; it is probably a segment of the superior orbital fissure. The foramen is really a canal running from the middle cranial fossa to the pterygo-palatine fossa, and transmits the second or maxillary division of the trigeminal.

(*c*) The **foramen ovale** at birth is a gap in the hinder border of the great wing (ali-sphenoid) of the sphenoid, and is converted into a foramen by the petrosal; subsequently it becomes complete in the sphenoid. It transmits the third or mandibular division of the trigeminal and the small or motor root, the small superficial petrosal nerve (which occasionally passes through a separate foramen), and the small meningeal artery with its venæ comitantes.

The ethmoidal canals.—These commence in the suture between the lamina papyracea and the frontal bone, and traverse the space between the upper surface of the lateral mass of the ethmoid and the horizontal plate of the frontal, to emerge on the cribriform plate; they are situated outside the dura mater. The anterior foramen transmits the anterior ethmoidal branch of the ophthalmic, which subsequently gains the nasal cavity by passing through the ethmoidal fissure by the side of the crista galli.

The **infra-orbital canal** indicates the line of confluence of the maxillary and malar centres of the maxilla; occasionally it is completed by the zygomatic; rarely it is incomplete above, and communicates by a narrow fissure with the orbit. It lodges the infra-orbital nerve and artery.

The **zygomatico-temporal foramen** is situated in the suture between the zygomatic and the greater wing of the sphenoid (ali-sphenoid); it transmits the temporal branch of the zygomatic nerve and a branch of the lacrimal artery. In the adult this foramen may be wholly confined to the zygomatic bone.

The **zygomatico-facial canals** traverse the zygomatic bone, and indicate the line of confluence of the two chief centres for this bone. The facial twigs of the zygomatic nerve issue from them accompanied by arterial twigs.

The **spheno-palatine foramen** is a deep groove between the orbital and sphenoidal processes of the palate bone, converted into a foramen by the sphenoidal concha. It is traversed by the naso-palatine nerve and artery as they enter the nasal from the pterygo-palatine fossa.

Scarpa's foramina are two minute openings in the meso-palatine suture where it is in relation with the incisive fossa. They are traversed by the naso-palatine nerves.

The **pharyngeal foramen** is situated between the sphenoidal process of the palate bone, the medial pterygoid plate of the sphenoid, and the sphenoidal concha. The pharyngeal branch of the spheno-palatine ganglion and a branch of the spheno-palatine artery pass through it.

The **pterygoid** (Vidian) **canal** is trumpet-shaped: the narrower end is situated in the foramen lacerum; the broader orifice opens on the posterior wall of the pteryo-palatine fossa. The canal is 10 mm. long; in the fœtal skull it is a chink between the base of the medial pterygoid plate, the ali-sphenoid, and the lingula of the sphenoid. The canal is traversed by the Vidian branch of the spheno-palatine ganglion and the Vidian artery.

The **posterior** (greater) **palatine canal** is a passage left between the maxilla, the vertical plate and tuberosity of the palate bone and the medial pterygoid plate; it commences on the hard palate by the greater palatine foramen. The descending palatine nerve and artery traverse this canal. Several foramina open from it. In the suture between the vertical plate of the palate bone and the maxilla, two small openings allow minute nerves to issue for the middle and inferior nasal conchæ. In the fissures between the tuberosities of the palate and maxillæ, and the pterygoid plates, the posterior and middle palatine nerves issue. These are sometimes called the posterior and middle (smaller) palatine canals.

The **mandibular** or **inferior dental canal** runs in the mandible between the dentary and Meckel's cartilage of the mandible. The posterior orifice of the canal is the mandibular (inferior dental) foramen; the anterior orifice is the mental foramen. The inferior alveolar nerve and artery enter the canal at its posterior orifice; the mental foramen allows the mental nerve to escape from the canal accompanied by the mental artery.

Foramina transmitting the facial nerve and its branches.—The main trunk of the facial enters the internal auditory meatus and traverses the facial canal. In the early embryo the nerve lies on the petrosal, and is not covered in with bone until the fifth month of fœtal life. The terminal orifice, the **stylo-mastoid foramen**, is situated between the tympanic, tympanohyal, and epiotic elements of the complex temporal bone.

The **'iter chordæ posterius'** is a chink between the squamosal and the tympanic elements, and allows the chorda tympani nerve to enter the tympanum. The fissure of exit for this nerve is the subdivision of the petro-tympanic fissure termed the canal of Huguier, or **'iter chordæ anterius.'** The **petro-tympanic fissure** lies between the tympanic plate and the squamosal. It transmits the tympanic branch of the internal maxillary artery, and lodges the anterior process of the malleus.

The **inferior orbital** (spheno-maxillary) **fissure** is situated between the posterior border of the orbital plate of the maxilla and a smooth ridge on the orbital surface of the great wing of the sphenoid. It transmits the superior maxillary division (second) of the fifth nerve, the zygomatic nerve, branches of the spheno-palatine ganglion to the orbit, and a communicating vein from the ophthalmic to the pterygoid plexus.

C. THE THORAX

The **thorax** is a bony cage formed by the thoracic vertebræ already described, the ribs with their costal cartilages, and the sternum.

THE RIBS

The **ribs** [costæ] (figs. 154, 155) twelve in number on each side, constitute a series of narrow, flattened bones, extending from the sides of the thoracic vertebræ toward the median line on the anterior aspect of the trunk. The anterior ends of the first seven pairs are connected, by means of their costal cartilages, with the sides of the sternum, and on this account the first seven ribs on each side are

termed **true** or sternal ribs. The remaining five pairs, known as **false** or asternal ribs, may be arranged in two sets:—one, including the eighth, ninth, and tenth ribs, in which the cartilages of the anterior extremities are connected together, and the other, including the eleventh and twelfth, in which the anterior extremities, tipped with cartilage, are free. The eleventh and twelfth are known, in consequence, as the **floating** ribs. Thus, the first seven are **vertebro-sternal;** the eighth, ninth, and tenth, **vertebro-chondral;** the eleventh and twelfth, **vertebral** ribs.

The ribs increase in length from the first to the seventh, and decrease from the seventh to the twelfth. They also vary in their direction, the upper ones being less oblique than the lower. The obliquity is greatest at the ninth rib and gradually decreases from the ninth to the twelfth.

Typical characters of a rib (fig. 154).—The seventh is regarded as the most typical rib. It presents for examination a vertebral extremity or **head;** a narrow portion or **neck;** a **sternal** extremity; and an intermediate portion, the **body** or **shaft.**

The **head** [capitulum costæ] presents an **articular surface** made up of two articular facets separated by a horizontal crest [crista capituli]. The crest is connected by an interarticular ligament with an intervertebral disc, and the facets articulate with the costal pits on the sides of the bodies of two vertebræ (sixth and seventh). As a rule, the lower facet is the larger, and articulates with the thoracic vertebra, to which the rib corresponds in number. This is the primary facet, and is the one represented in those ribs which possess only a single facet on the rib-head. The anterior margin is lipped for the attachment of the radiate ligament.

The **neck** [collum costæ] is that portion of the rib extending from the head to the **tubercle.** It is flattened from before backward and the posterior surface is in relation with the transverse process of the lower of the two vertebræ with which the head articulates; it forms the anterior boundary of the **costo-transverse foramen,** and is rough where it is attached to the neck (middle costo-transverse) ligament. The anterior surface is flat and smooth. The superior border of the neck, continuous with the corresponding border of the shaft, presents a rough crest [crista colli] for the anterior costo-transverse ligament. The inferior border of the neck is rounded and continuous with the ridge of the **costal groove.** This difference in the relation of the neck, to the upper and lower borders of the rib-shaft, is useful in determining to which side a rib belongs.

The **tubercle,** situated behind at the junction of the neck with the shaft, consists of an upper and lateral part, rough for the attachment of the posterior costo-transverse ligament, and a lower and medial part, bearing a facet for articulation with a pit near the tip of the transverse process. The tubercle projects below the lower edge of the rib to form a crest, marking the beginning of the costal groove.

The **body** is strongly curved and presents for examination two surfaces and two borders. At first the curve is in the same plane as the neck, but it quickly turns forward at a spot on the posterior surface of the shaft known as the **angle,** where it gives attachment to the *ilio-costalis* muscle and some of its subdivisions. The rib has also a second or upward curve, beginning at the angle. These curves are expressed by describing the main curve as disposed around a vertical, and the second or upward curve around a second transverse axis.

When a rib, except the first, second, and twelfth, is laid with its lower border upon the table, the rib-head rises and the rib touches the table at two places, viz., at the anterior end, and in the neighbourhood of the angle.

Besides the two curves now described, the rib is slightly twisted on itself, so that the surfaces which look medially and laterally behind are placed obliquely in front and look downward as well as medially, and upward as well as laterally.

The external surface of the rib is convex, and gives attachment to muscles. Near its anterior extremity it forms a somewhat abrupt curve, indicated by a ridge on the bone, which gives attachment to the *serratus anterior* (*magnus*) muscle, and is sometimes called the **anterior angle.**

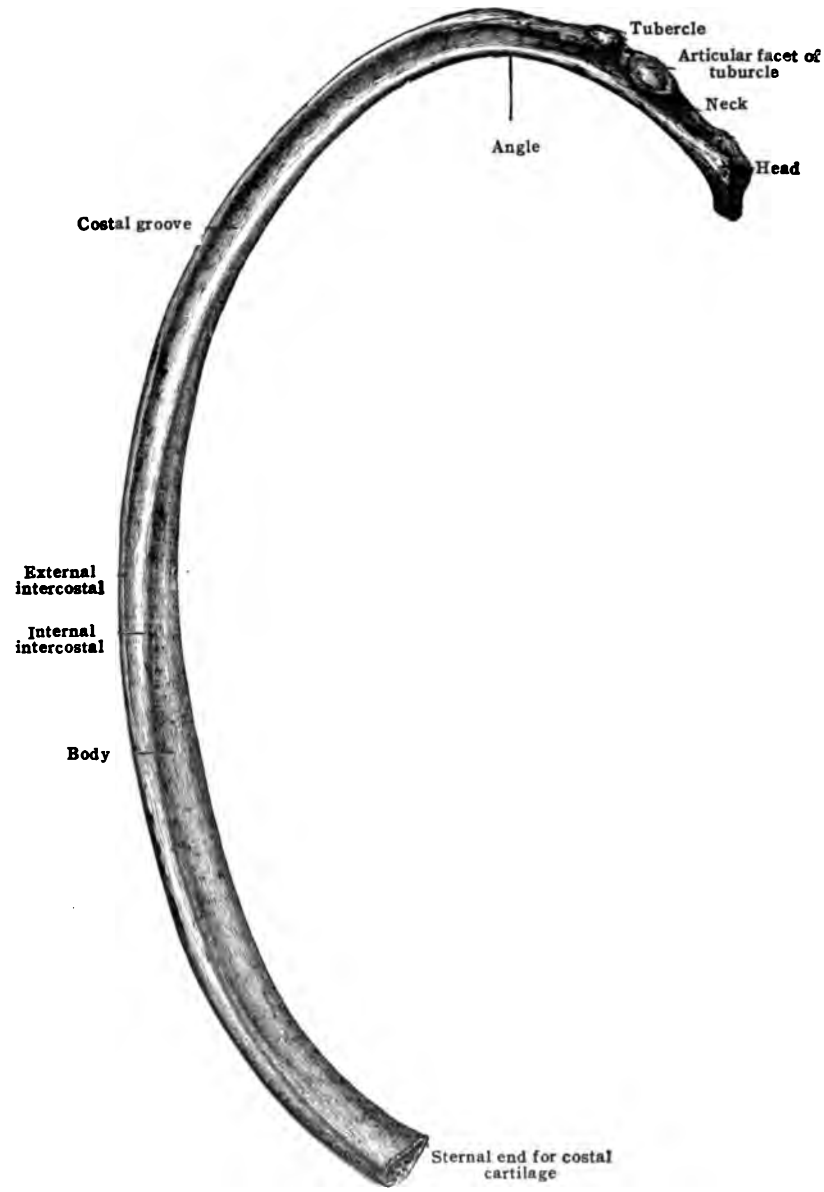
The internal surface is concave and presents near its inferior border the **costal groove** [sulcus costæ]. The groove is best marked near the angle, and gradually becomes shallower toward the anterior extremity of the rib, where it is finally lost; it lodges the intercostal vessels and nerve. The ridge limiting the

groove above is continuous with the inferior border of the neck of the rib, and gives attachment to the *internal intercostal* muscle.

The superior border is rounded, and affords attachment to the *internal* and *external intercostal* muscles. The inferior border commences abruptly near the angle, and gives attachment to the *external intercostal* muscle.

The **sternal** end of the shaft is cupped for the reception of the costal cartilage.

FIG. 154.—THE SEVENTH RIB OF THE LEFT SIDE. (Seen from below.)



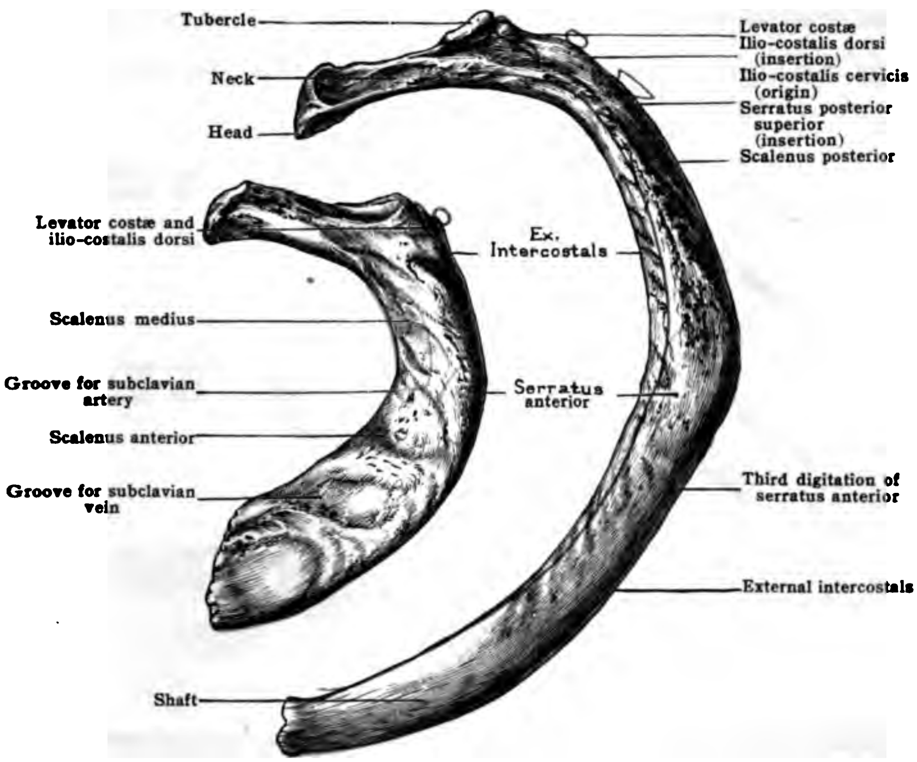
Blood-supply.—The ribs are very vascular and derive numerous branches from the intercostal arteries. The branches in the shaft run toward the vertebral end, whilst those in the head and neck run, as a rule, toward the shaft. In the neighbourhood of the tuberosity the vessels do not seem to have any constant arrangement.

Peculiar ribs(figs. 155, 156).—Several of the ribs present certain peculiarities and differ in many particulars from the general description given above. These are the **first, second, tenth, eleventh,** and **twelfth.**

The **first rib** is the broadest, flattest, strongest, shortest, and most curved of all the series. It is not twisted, and is so placed that its superior surface looks forward as well as upward, and its inferior surface backward as well as downward. The head is small, and as a rule is furnished

with only one articular facet. The neck, longer than that of most of the ribs, is slender and rounded. The tubercle is large and prominent. The shaft lies for its whole extent nearly in one plane, has no angle, and is curved in one direction only, i. e., around a vertical axis. The superior surface presents two shallow grooves, separated near the inner border by a rough surface (**scalene tubercle** or tubercle of Lisfranc) for the *scalenus anterior* muscle. The groove in front of this surface is for the subclavian vein, and the groove behind it is for the subclavian artery and a nerve trunk passing to the brachial plexus. Between the groove for the artery and the tubercle is a rough surface for the insertion of the *scalenus medius*, and between the groove and the outer margin is an area for the origin of the *serratus anterior* (*magnus*). The inferior surface is uniformly flat and lacks a subcostal groove. By the lateral portion, which is rough, it gives attachment to the internal intercostal muscle; the remainder of the inferior surface is in relation to pleura and lung. The lateral border is thick and rounded, and gives attachment to the *external intercostal* muscle, whilst the medial border, thin, sharp, and concave, receives the attachment of the fascia (Sibson's) covering the dome of the pleura. The anterior extremity is thick and broad, and its upper margin, as well as the cartilage to which it is joined, afford attachment to the costo-clavicular ligament and the *subclavius* muscle. The costal cartilage of this rib is directly united to the manubrium sterni, and occasionally the cartilage and the adjoining part of the anterior extremity of the rib are replaced by fibrous tissue.

FIG. 155.—FIRST AND SECOND RIBS. (Viewed from above.)



The rib derives its nutrition mainly from the superior intercostal branch of the subclavian artery.

The **second rib** is much longer than the first, and although like it in being strongly curved round a vertical axis, in its form and general characters there is a closer resemblance to the ribs lower down in the series. The head is round and presents two facets, the costal groove is present, though faintly marked, and an angle is situated near the tubercle. The specially distinguishing feature of the rib, however, is a well-marked tuberosity on its outer surface somewhat near the middle, for the origin of a part of the first digitation, and the whole of the second digitation of the *serratus anterior* (*magnus*). Between the tuberosity and the tubercle the outer surface is smooth and rounded and gives attachment to the *scalenus posterior*, the *serratus posterior superior*, the *ilio-costalis cervicis* (*cervicalis ascendens*), and the *ilio-costalis dorsi* (*accessorius*). The internal surface is smooth and in relation to the pleura. The borders give attachment to the *intercostal* muscles, the upper, to those of the first space, the lower, to those of the second. The shaft of the second rib is not twisted on its own axis, so that both ends can lie flat on the table. The second rib receives vessels from the superior intercostal branch of the subclavian artery and the first aortic intercostal.

The **tenth rib** is distinguished by a single facet on the head for articulation with the body of the tenth thoracic vertebra. Occasionally there are two facets, in which case the rib articulates also with the ninth thoracic vertebra. The tenth rib, like the ribs immediately above, is long, curved, presents a deep costal groove, a well-marked tuberosity and an angle. It may

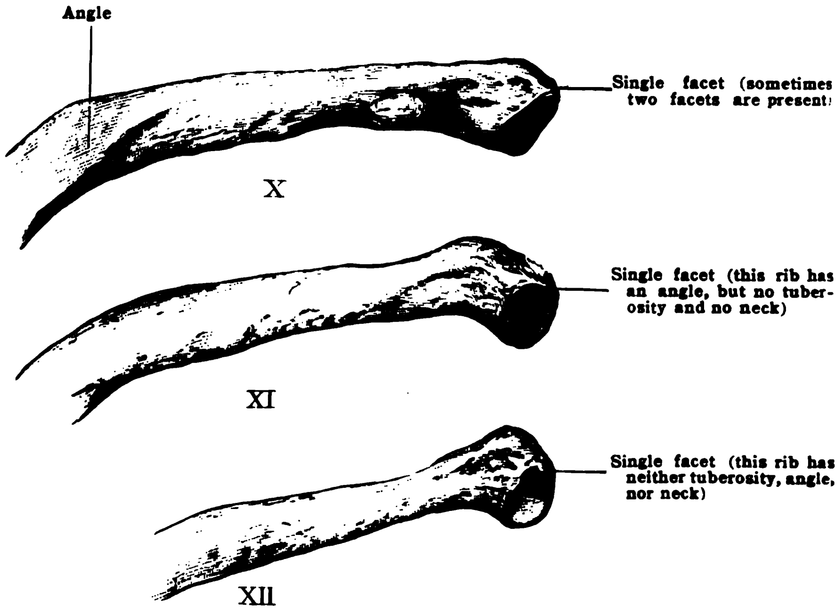
be noted, however, that the distance between the tubercle and the angle in this rib is greater than in the ribs above. Speaking generally, the distance between these points increases from above downward—a disposition which is useful in at once determining if any given rib belongs to the upper or lower end of the series.

The eleventh rib is peculiar in that it has a single facet on the head, a feebly marked angle some distance from the head, a shallow costal groove, no tubercle, and no neck. The tubercle is sometimes represented by a slight elevation or roughness without any articular facet. The anterior extremity is pointed.

The **twelfth rib** has a large head furnished with one facet for articulation with the root (pedicle) of the twelfth thoracic vertebra. The shaft is narrow and extremely variable in length (3 to 20 cm.). It is usually somewhat longer than the first rib, but it may be shorter. There is no tubercle, no angle, no neck, no costal groove. The anterior extremity is pointed. Posteriorly, the upper border is smooth and somewhat rounded; the lower border is sharp and rough.

The **costal cartilages** are bars of hyaline cartilage attached to the anterior extremities of the ribs, and may be regarded as representing unossified epiphyses. Like the shaft of a rib, each cartilage has an outer and inner surface. The outer surfaces give origin and insertion to large muscles, and the inner surfaces, from the second to the sixth inclusive, are in relation with the *transversus thoracis* (*triangularis sterni*). The upper and lower borders serve for the attachment of the *internal intercostal* muscles. The upper seven cartilages, and occasionally the eighth, are connected with the sternum. Of these, the first fuses with the manubrium sterni and the remaining six are received into small articular concavities, and retained by means of ligaments.

Fig. 156.—The Vertebral Ends of Tenth, Eleventh, and Twelfth Ribs.



The cartilages of the vertebro-chondral ribs are united to one another and to the seventh costal cartilage by ligaments (sometimes by short vertical bars of cartilage), while those of the vertebral ribs form no such attachment, but lie between the abdominal muscles. The inner surfaces of the lower six costal cartilages afford attachment to the *diaphragm* and the *transversalis* muscle.

Each of the second, third, fourth, and fifth costal cartilages articulates with the side of the sternum, at a point corresponding to the junction of two sternebræ. The sixth and seventh (and eighth when this reaches the sternum) are arranged irregularly. As a rule, the sixth lies in a recess at the side of the fifth sternebra; the seventh corresponds to the line of junction of the meso- and metasternum; and the eighth articulates with the metasternum (see figs. 158, 161).

Blood-supply.—The costal cartilages derive their blood-supply from the terminal twigs of the aortic intercostals and from the internal mammary arteries.

Ossification.—At the eighth week of intra-uterine life the ribs are cartilaginous. About this date a nucleus appears near the angle of each rib, and spreads with great rapidity along the shaft, and by the fourth month reaches as far as the costal cartilage. At this date the length of rib-shaft bears the same proportion to that of the costal cartilage as in adult life. Whilst the ribs are in a cartilaginous condition, the first eight reach to the side of the sternum, and even after ossification has taken place, the costal cartilage of the eighth rib, in many instances, retains its articulation with the sternum up to as late as the eighth month (fig. 158). This relationship may persist through life, but usually the cartilage retrogresses, and is replaced by ligamentous tissue. About the fifteenth year a secondary centre appears for the head of each rib, and a little later one makes its appearance for the tubercle, except in the eleventh and twelfth ribs. Frequently epiphyses are developed on both parts of the tubercle (see figs. 159 and 160). The

epiphyses fuse with the ribs about the twenty-third year. The rib-shaft increases in length mainly at its line of junction with the costal cartilage.

Variations in the Number and Shape of the Ribs

The ribs may be increased in number by addition either at the cervical or lumbar end of the series, but it is extremely rare to find an additional rib or pair of ribs in both the cervical and lumbar regions in the same subject.

FIG. 157.—RIB AT PUBERTY.

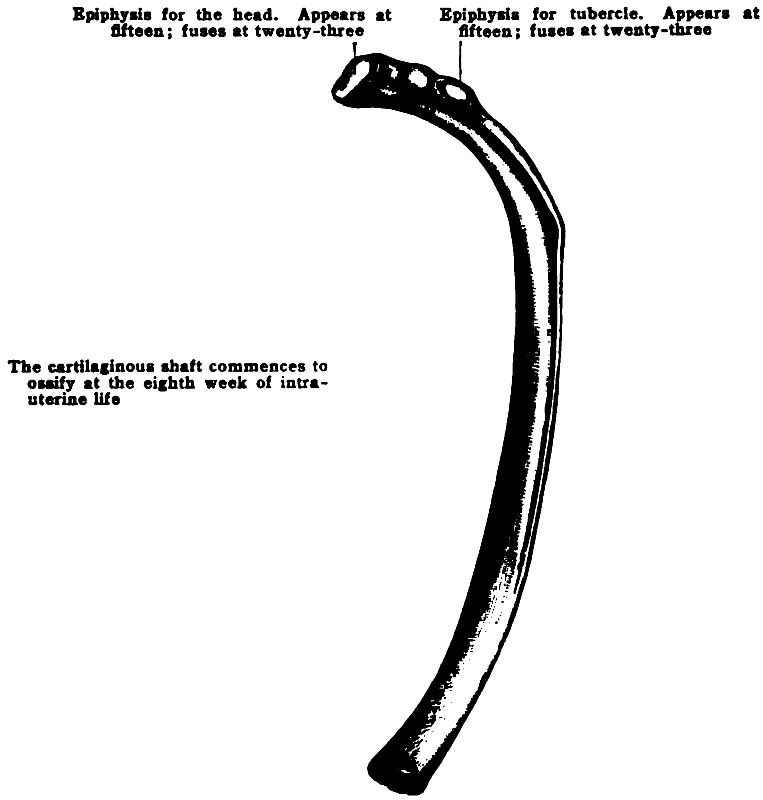
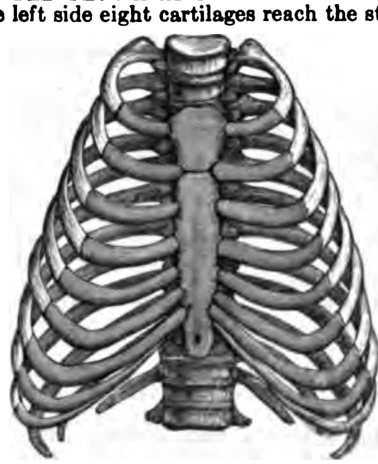


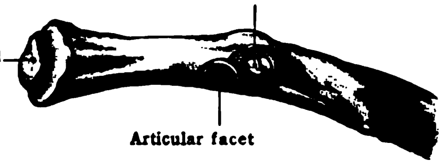
FIG. 158.—THE THORAX AT THE EIGHTH FŒTAL MONTH.
(On the left side eight cartilages reach the sternum.)



Cervical ribs are fairly common; as a rule, they are of small size and rarely extend more than a few millimeters beyond the extremity of the transverse process (see p. 35). Rarely they exceed such insignificant proportions and reach as far as the sternum; between these two extremes many varieties occur. In one case Turner was able to make a thorough dissection of a specimen in which a complete cervical rib existed. Its head articulated with the body of the

seventh cervical vertebra and had a radiate ligament. The tubercle was well developed, and articulated with the transverse process. The costal cartilage blended with that of the first thoracic rib, and gave attachment to the costo-clavicular ligament. Between it and the first thoracic rib there was a well-marked intercostal space occupied by intercostal muscles. It received the attachment of the *scalenus anterior* and *medius* muscles, and it was crossed by the subclavian artery and vein. The nerves of the intercostal space were supplied by the eighth cervical and first thoracic. The artery of the space was derived from the deep cervical, which, with the superior intercostal, arose from the root of the vertebral. The head of the first thoracic rib in this specimen articulated with the seventh cervical, as well as with the first thoracic vertebra. An interesting fact is also recorded in the careful account of this specimen. There was no movable twelfth thoracic rib on the same side as this well-developed cervical rib, and the twelfth thoracic vertebra had mammillary and accessory processes, and a strong elongated costal process, and was in linear series with the lumbar transverse processes.

FIG. 159.—POSTERIOR PORTION OF THE SIXTH RIB IN THE FIFTEENTH YEAR. (After Toldt.)



Gruber and Turner, from a careful and elaborate study of this question, summarise the variations in the cervical rib thus:—It may be very short and possess only a head, neck, and tubercle. When it extends beyond the transverse process, its shaft may end freely or join the first thoracic rib: this union may be effected by bone, cartilage, or ligament. In very rare instances it may have a costal cartilage and join the manubrium of the sternum. Not unfrequently a process, or eminence, exists on the first thoracic rib at the spot where it articulates with a cervical rib.

Lumbar ribs are of less significance than cervical ribs and rarely attain a great length. Their presence is easily accounted for, as they are the differentiated costal elements of the transverse processes. They are never so complete as the cervical ribs, and articulate only with the transverse processes; the head never reaches as far as the body of the vertebra, and there is no neck or tubercle. An extra *levator costæ* muscle is associated with a lumbar rib.

FIG. 160.—POSTERIOR PORTION OF THE SIXTH RIB IN THE EIGHTEENTH YEAR. (After Toldt.)

Not the least interesting variation of a rib is that known as the **bicipital rib.** This condition is seen exclusively in connection with the **first thoracic rib.** The vertebral end consists of two limbs which lie in different transverse planes. These bicipital ribs have been especially studied in whales and man. This abnormality is due to the fusion of two ribs, either of a cervical rib with the shaft of the first thoracic; or the more common form, the fusion of the first and second true ribs.

Among unusual variations of ribs should be mentioned the replacement of the costal cartilage and a portion of the rib-shaft by fibrous tissue, a process which occurs normally in the case of the eighth rib during its development.

Sometimes the shafts of two or more ribs may become united by small quadrilateral plates of bone extending across the intercostal spaces.

THE STERNUM

The **sternum** (figs. 161, 162) is a flat, oblong plate of bone, situated in the anterior wall of the thorax, and divisible into three parts, called respectively—(1) the **manubrium sterni** (presternum), (2) the **gladiolus** (mesosternum), constituting the **body** of the bone, and (3) the **xiphoid** (or ensiform) **process** (metasternum). In the young subject it consists of six pieces or segment (sternebræ). Of these, the first remains separate throughout life and forms the **manubrium**; the suc-

ceeding four segments fuse together, forming the body; whilst the lowest segment, also distinct until middle life, is represented by the xiphoid process.

In its natural position the sternum is inclined obliquely from above downward and forward, and corresponds in length to the spine from the third to the ninth thoracic vertebra. It is not of equal width throughout, being broader above at the manubrium and narrow at the junction of this piece with the body. Toward the lower part of the body the sternum again widens, and then suddenly contracts at its junction with the xiphoid process which constitutes the narrowest part.

The **manubrium** or first piece of the sternum forms the broadest and thickest part of the bone, and is of a somewhat triangular form with the base directed upward and the apex downward. It presents for examination two surfaces and four borders. The **anterior surface** [planum sternale] is largely subcutaneous. It is slightly convex and directed obliquely upward and forward, is smooth and gives origin on each side to the sternal head of the *sterno-mastoid* and the *pectoralis major*. The **posterior surface,** almost flat, and directed downward and backward, affords origin near the lateral margins on each side, to the *sterno-hyoid* muscle above and the *sterno-thyreoid* muscle below. Of the four borders, the **superior** is the longest and much the thickest. In the middle is a curved, non-articular depression, called the **jugular** (interclavicular) **notch,** to which the fibres of the interclavicular ligament are attached, and at either end is an oval articular surface [incisura clavicularis], somewhat saddle-shaped and directed upward, backward, and laterally for the reception of the medial end of the clavicle. The circumference of the articular surface gives attachment to the sterno-clavicular ligaments. The **lateral borders** slope from above downward and medially and each presents an irregular surface above for the first costal cartilage and a small facet below, which, with an adjoining facet on the body, forms a notch for the second costal cartilage. The two articular surfaces are separated by a narrow curved edge in relation with the *internal intercostal* muscle of the first space. The **lower border** is thick and short and presents an oval rough surface which articulates with the upper border of the body, forming the **sternal synchondrosis.** The two opposed surfaces are separated by a fibro-cartilaginous disc, which may, however, become partially ossified in advanced age, and at the position of the joint there is usually an angle—the **angle of the sternum**—which can be felt as a transverse ridge beneath the skin. This is useful in locating the position of the second rib in the living subject.

The **body** (gladiolus) or second piece of the sternum is longer, narrower, and thinner than the manubrium. It is widest opposite the notches for the fifth costal cartilages and becomes narrower above and below. The **anterior surface** is flat, directed upward and forward, and marked by three transverse elevations which indicate the lines of junction of its four component parts. It gives attachment on each side to fibres of the *pectoralis major,* and occasionally presents a foramen—the **sternal foramen**—situated at the junction of the third and fourth pieces of the bone. The **posterior surface** is slightly concave, marked by lines corresponding to those on the anterior surface, and below gives attachment on each side to fibres of the *transversus thoracis* (*triangularis sterni*). The **lateral borders** present four whole notches [incisuræ costæ] and two half-notches on each side, which articulate with the costal cartilages of the second to the seventh ribs inclusive; the two half-notches are completed by corresponding notches on the manubrium and the xiphoid process. Between the articular depressions the lateral border is curved and in relation to the *internal intercostal* muscles.

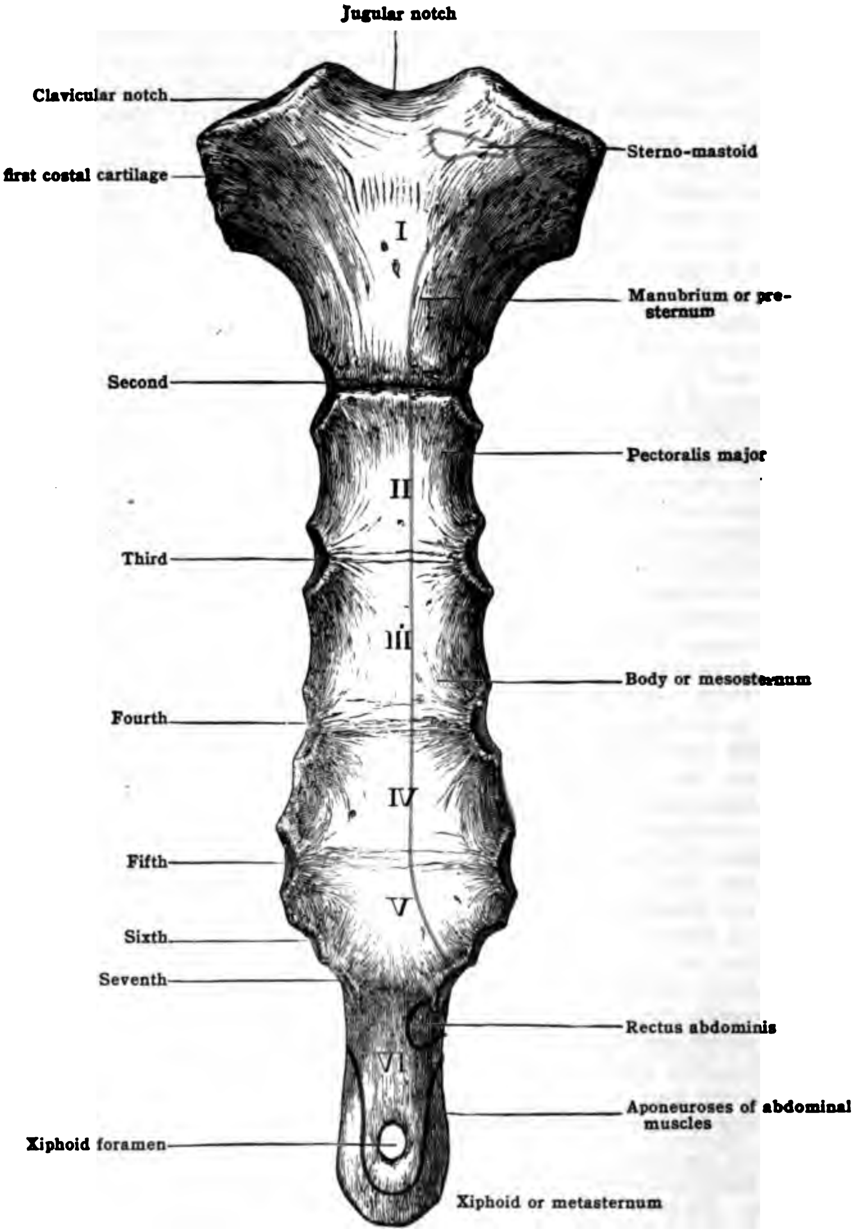
In order to appreciate the nature of these articular notches, it is advantageous to study the sternum in a young subject. Each typical **sternebra** presents four angles at each of which is a demi-notch. Between every two sternebræ there is an intersternebral disc so that when in position, each notch for a costal cartilage is formed by a sternebra above and below and an intersternebral disc in the middle, thus repeating the relation of the rib-head to the vertebral centre. Later in life these fuse more or less together, except in the case of the first and second sternebræ, which usually remain separate to the end of life. The first (pre-sternum) is the most modified of all the sternebræ, and differs from them in the fact that the costal cartilage of the first rib is continuous with it, and in fact that it supports the clavicles. Occasionally a rounded pisiform bone is seen on each side, medial to the articular notch for the clavicle; these are the **supra-sternal** bones.

The **superior border** of the sternal body presents an oval facet for articulation (synchondrosis) with the manubrium. The **inferior border** is short and articu-

lated with the xiphoid process, forming the meso-metasternal joint, the two opposed surfaces being separated by a layer of cartilage so long as they are not united by bone.

The **xiphoid** (ensiform) **process** is the thin, elongated process projecting downward between the cartilages of the seventh ribs. It is the least developed

FIG. 161.—THE STERNUM. (Anterior view.)



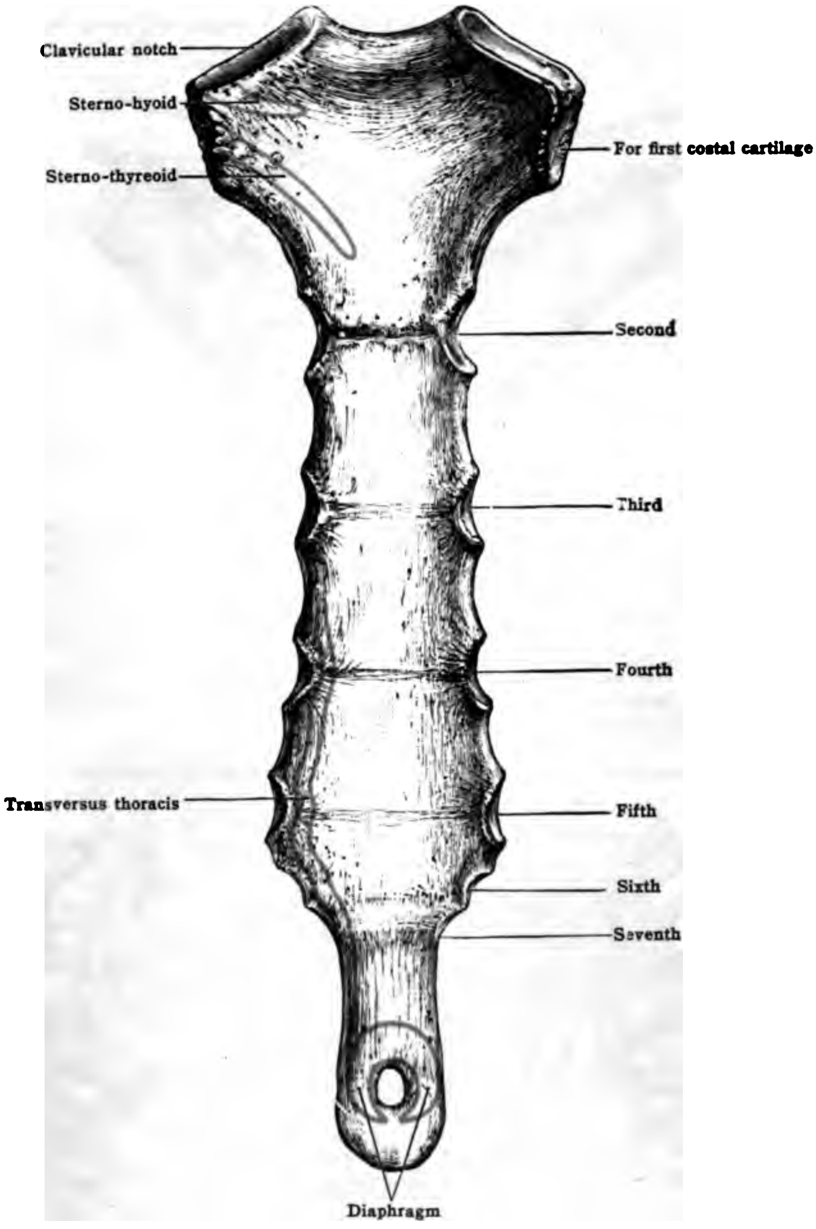
part of the sternum and is subject to many variations in form, being sometimes pointed, broad and thin, occasionally bifid or perforated by a foramen, and sometimes bent forward, backward, or deflected to one side. In structure it is cartilaginous in early life, partially ossified in the adult, but in old age it tends to become ossified throughout and to fuse with the body.

The **anterior surface** of the xiphoid process gives attachment to a few fibres of the *rectus abdominis* muscle and the chondro-xiphoid ligament, the **posterior surface** to the sternal fibres of the *diaphragm*, and the lowest fibres of the *transversus thoracis* (*triangularis sterni*), whilst

the lateral margins receive the aponeuroses of the abdominal muscles. Its tip is directly continuous with the linea alba.

Differences according to sex.—The sternum differs somewhat in the two sexes. The female sternum is relatively shorter, the diminution being almost confined to the body. In the male the body is more than twice as long as the manubrium, whereas in the female it is usually less than twice the length of the first piece.

FIG. 162.—THE STERNUM. (Posterior view.)



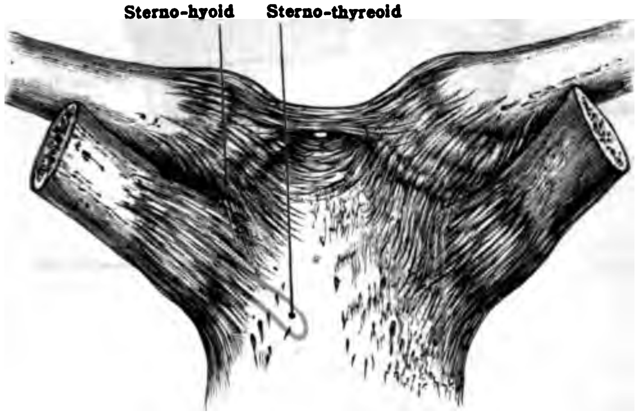
Structurally the sternum is composed of cancellous tissue covered with an outer layer of compact tissue. Its arterial supply is derived mainly from the sternal and perforating branches of the internal mammary.

Development of the sternum.—The osseous sternum is preceded by a continuous or non-segmented central sternal cartilage formed in the following way When the cartilaginous ribs first appear in the embryo, their anterior or ventral ends fuse together on either side of the middle line. For some time a median fissure is present, bordered by two sagittally directed strips of cartilage with each of which at first nine ribs are joined. As development proceeds the two strips come into contact in the middle line and fuse from before backward to form a median sternal cartilage. The eighth cartilage generally loses its sternal attachment, although in some cases it remains permanently articulated with the side of the ensiform process. The ninth

costal cartilage becomes subdivided, one part remaining attached to the sternum and forming the xiphoid process, whilst the end still continuous with the rib acquires a new attachment to the eighth cartilage. The ends adherent to the sternum may remain separate and give rise to a bifid xiphoid process, though much more frequently they unite, leaving a small foramen.

At first, therefore, the sternum and costal cartilages are continuous. A joint soon forms between the presternum and mesosternum, and others between the costal cartilages and the sternum (except in the case of the first) quickly follow. The division of the mesosternum into segments is a still later formation and arises during the process of ossification.

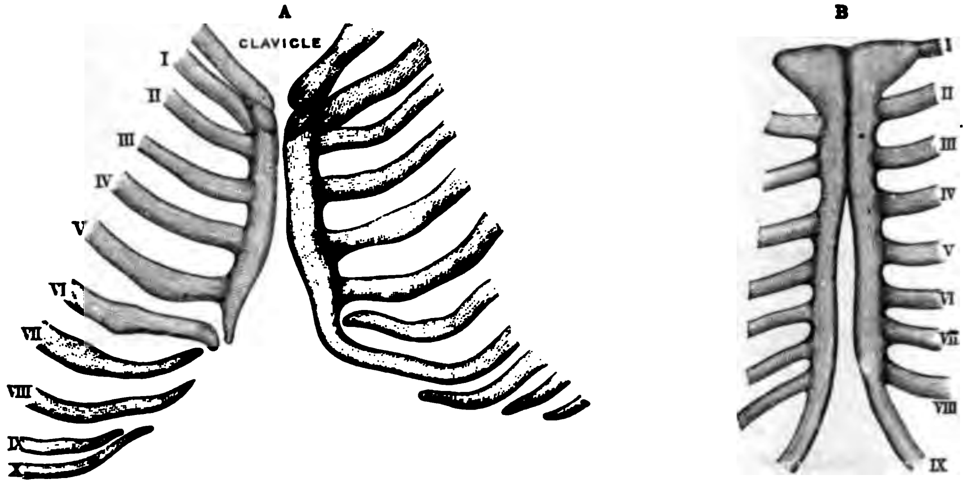
FIG. 163.—POSTERIOR SURFACE OF THE MANUBRIUM (PRE-STERNUM), WITH STERNAL ENDS OF CLAVICLES AND THE FIRST COSTAL CARTILAGES.



On the other hand, a view has been advanced by Professor A. M. Paterson that the sternum is not a bilateral structure, but is laid down, as shown in human sterna of the third month, as a simple median band of hyaline cartilage, in complete fusion with the costal cartilages on each side and presenting no differentiation of its component parts. From a study of the earliest stages of the development of the sternum, its comparative anatomy and structure, Professor Paterson has, moreover, brought forward evidence which indicates its independence in the first instance of costal elements and its genetic association with the shoulder girdle.

Ossification.—The ossification of the sternum is slow and irregular. The process begins in the presternum (manubrium) by a single centre about the sixth month of intra-uterine life, though occasionally other accessory centres are superadded.

FIG. 164.—TWO STAGES IN THE FORMATION OF THE CARTILAGINOUS STERNUM. (After Ruge.)



The mesosternum (body) usually ossifies from seven centres. The upper segment ossifies from a single median nucleus about the eighth month, and below this, three pairs of ossific nuclei appear, which may remain for a long time separate. Of these, two pairs for the second and third segments are visible at birth, and those for the lower segment make their appearance toward the end of the first year. The various lateral centres unite in pairs, so that at the sixth year the sternum consists of six sternebræ, the lowest (metasternum) being cartilaginous. Very often, however, there are only four centres of ossification in the gladiolus, as shown in fig. 165. Gradually the four pieces representing the mesosternum fuse with one another, and

FIG. 165.—OSSIFICATION OF THE STERNUM.
, common arrangement of the ossific centres. B, showing accessory centre in the manubrium sterni, and bilateral centres in the second, third, and fourth pieces of the body.

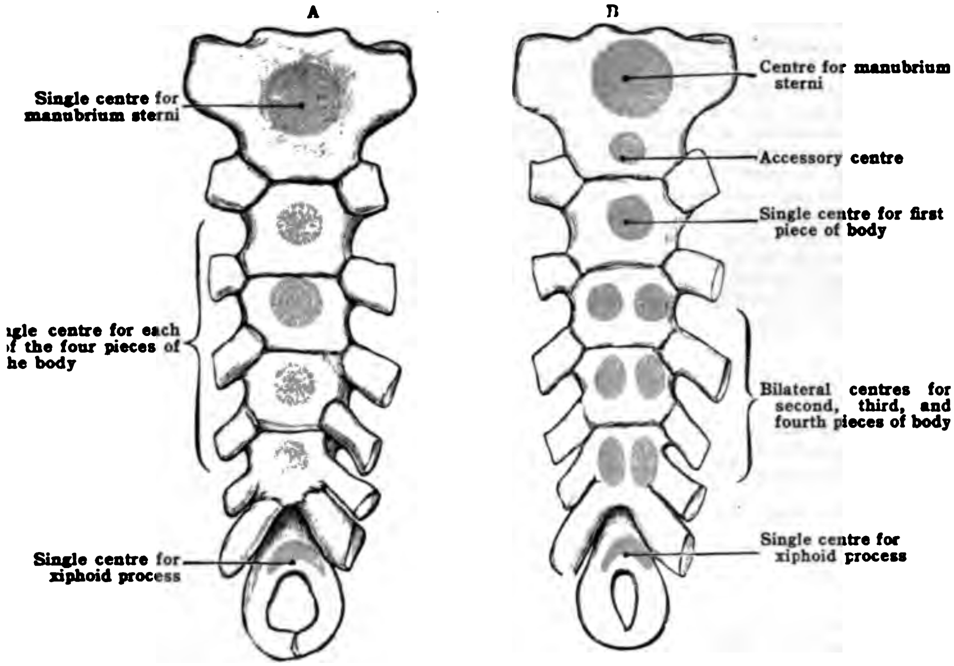
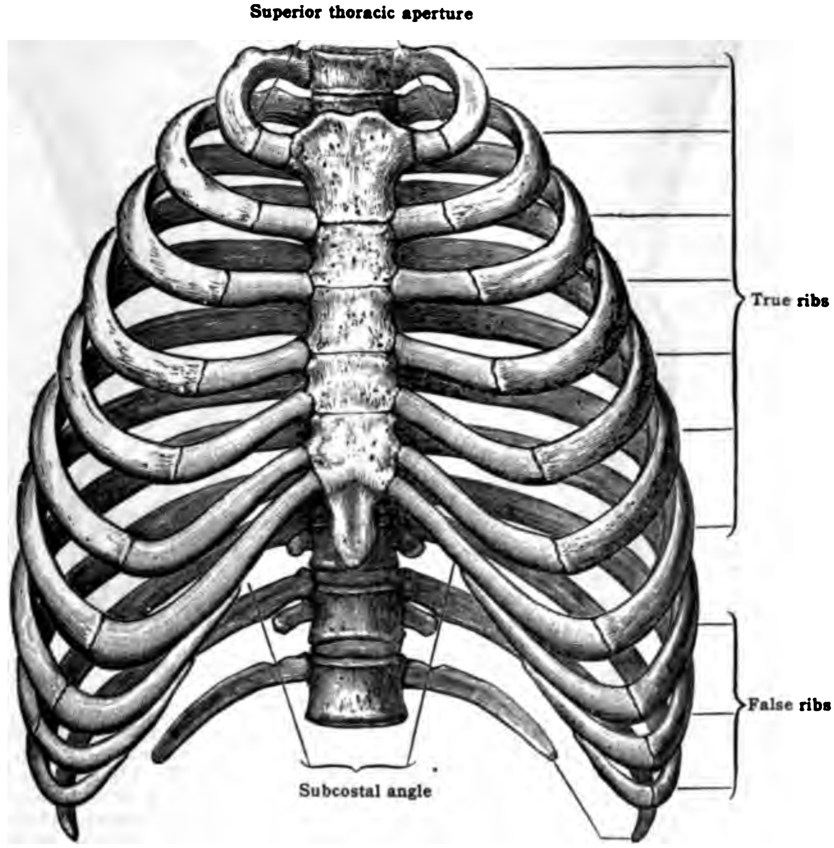


FIG. 166.—THE THORAX. (Front view.)



at twenty-five they form a single piece, but exhibit, even in advanced life, traces of their original separation. A sternal foramen is usually the result of non-union across the middle line or a defect of ossification.

The metasternum is always imperfectly ossified, and does not join with the mesosternum till after middle life. The presternum and mesosternum rarely fuse. The dates given above for the various nuclei, and for the union of the various segments, are merely approximate, hence the sternum affords very uncertain data as to age.

Abnormalities of the Sternum.—The mode of development of the sternum as described above is of importance in connection with some deviations to which it is occasionally subject. In rare instances the two lateral halves fail to unite, giving rise to the anomaly of a completely cleft sternum. The union of the two halves may occur in the region of the manubrium and fail below, whilst in other cases the upper and lower parts have fused but remain separate in the middle. The clefts are in many instances so small as not to be of any moment, and are not even recognised until the skeleton is prepared. In a few individuals, however, they have been so extensive as to allow the pulsation of the heart to be perceptible to the hand, and even to the eye, through the skin covering the defect in the bone.

A common variation in the sternum is asymmetry of the costal cartilages. Instead of corresponding, the cartilages may articulate with the sternum in an alternating manner. The cause of this asymmetry is not known.

THE THORAX AS A WHOLE

The bony thorax (fig. 166) is somewhat conical in shape, deeper behind than in front and compressed antero-posteriorly, so that in the adult it measures less in the sagittal than in the transverse axis. The **posterior** wall, formed by the thoracic vertebræ and the ribs as far

FIG. 167.—THE THORAX. (Posterior view.) The scapulæ are drawn from an *X*-ray photograph of a man 33 years old.

outward as their angles, is convex from above downward, and the backward curve of the ribs produces on each side of the vertebræ a deep furrow, the **costo-vertebral groove,** in which the *sacro-spinalis* (*erector spinæ*) muscle and its subdivisions are lodged. The **anterior wall** is formed by the sternum and costal cartilages. It is slightly convex and inclined forward in its lower part, forming an angle of about 20° with the vertical plane. The **lateral walls** are formed by the ribs from the angles to the costal cartilages. The top of the thorax presents an elliptical aperture, the **superior thoracic aperture,** which measures on an average 12.5 centimetres (5

inches) transversely and 6.2 centimetres (2½ inches) in its sagittal axis. It is bounded by the first thoracic vertebra behind, the upper margin of the manubrium sterni in front, and the first rib on each side. As the upper margin of the manubrium sterni is oftenest on a level with the disc between the second and third thoracic vertebræ, it follows that the plane of the opening is directed obliquely upward and forward. The angle of the sternum (*angulus Ludovici*) is usually opposite the body of the fifth thoracic vertebra and the xiphi-sternal junction corresponds to the disc between the ninth and tenth thoracic vertebræ. The lower aperture of the thorax is very irregular, and is formed by the twelfth thoracic vertebra behind, the twelfth ribs laterally, and in front by two curved lines, ascending one on either side from the last rib, along the costal margin to the lower border of the gladiolus. The two borders form the **costal arch,** which in the median line below the sternum forms the **infrasternal angle.** From this angle the xiphoid process projects downward. The intervals between the ribs are the **intercostal spaces,** and are eleven in number on each side.

The ratio of the sagittal and the transverse diameter of the thorax forms the **thoracic index,** which is higher in the female and in children, in whom the thorax is more rounded. In the embryo, the index is very much higher, the sagittal diameter being greater than the transverse. In the early embryo, the index is nearly 200; at birth it is about 90. In the adults it varies from 70 to 75, averaging 2 or 3 per cent. lower in the male than in the female. It is also lower in the negro than in the white race. (Rodes, Zeitschr. f. Morph. u. Anthrop., Bd. 9.)

II. THE APPENDICULAR SKELETON

A. BONES OF THE UPPER EXTREMITY

The bones of the upper extremity may be arranged in four groups corresponding to the division of the limb into four segments. In the *shoulder* are the clavicle and the scapula, which together constitute the pectoral or shoulder girdle; in the *arm* is the humerus; in the *forearm* are the radius and ulna; and in the *hand* the carpus, the metacarpus, and the phalanges.

THE CLAVICLE

The **clavicle** [clavicula] or collar bone (figs. 168, 169) is situated immediately above the first rib and extends from the upper border of the manubrium sterni, laterally and backward to the acromion process of the scapula. It connects the upper limb with the trunk, and is so arranged that whilst the medial end rests on the sternum and first costal cartilage, the lateral end is associated with the scapula in all its movements, supporting it firmly in its various positions and preventing it from falling inward on the thorax.

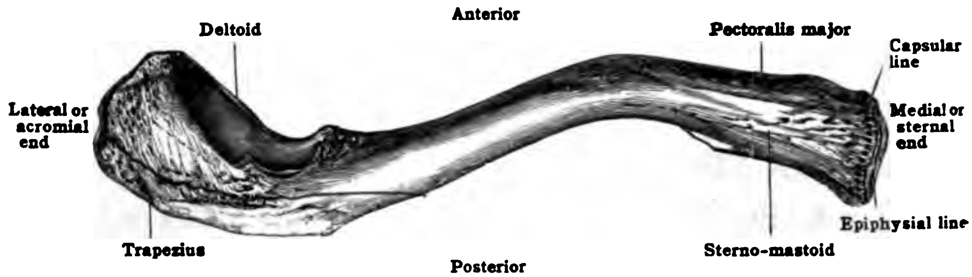
The clavicle is a long bone, and when viewed from the front presents a double curvature, so that it somewhat resembles in shape the italic letter *f*. The medial curve, convex forward, extends over two-thirds of the length of the bone; the lateral, concave forward, is smaller and confined to the lateral part. For descriptive purposes the clavicle may be divided into a medial prismatic portion, a lateral flattened portion, and two extremities.

Prismatic portion.—The medial two-thirds of the bone, extending from the sternal extremity to a point opposite the coracoid process of the scapula, has the form of a triangular prism. This portion, however, is subject to considerable variations of form, being more cylindrical in ill-developed specimens and becoming almost quadrangular when associated with great muscular development. In a typical specimen it is marked by three borders separating three surfaces. Of these, the **anterior surface** is convex and divided near the sternal end by a prominent ridge into two parts, a lower, giving origin to the clavicular portion of the *pectoralis major;* an upper, for the clavicular portion of the *sterno-cleido-mastoid.* Near the middle of the shaft the ridge disappears, the surface is smooth, and is covered by the *platysma myoides.* Occasionally this surface is pierced by a small canal, transmitting a cutaneous nerve from the cervical plexus. The **posterior surface** is concave, forming an arch over the brachial plexus and the subclavian artery, broadest medially and smooth in its whole extent. It gives origin near the sternal extremity to a part of the *sterno-hyoid* and occasionally to a few fibres of the *sterno-thyreoid.* Somewhere near the middle of this surface is a small foramen, directed laterally, for the chief nutrient artery of the bone, derived from the transverse scapular (suprascapular) artery. Sometimes the

foramen is situated on the inferior surface of the bone, in the subclavian groove. On the **inferior surface** near the sternal end is a rough area, the **costal tuberosity,** about three-quarters of an inch in length, for the attachment of the costo-clavicular ligament, by which the clavicle is fixed to the first rib. More laterally is a longitudinal groove for the *subclavius*, bordered by two lips, to which the sheath of the muscle is attached. To the posterior of the two lips the layer of deep cervical fascia which binds down the posterior belly of the omo-hyoid to the clavicle is also attached.

Of the three **borders,** the **superior** separates the anterior and posterior surfaces. Beginning at the sternal end, it is well-marked, becomes rounded and indistinct in the middle, whilst laterally it is continuous with the posterior border of the outer third. The **posterior border** separates the inferior and posterior surfaces and forms the posterior lip of the subclavian

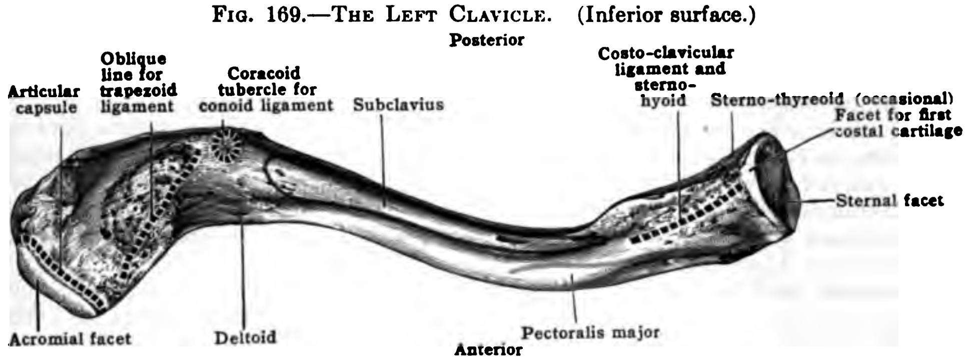
FIG. 168.—THE LEFT CLAVICLE. (Superior surface.)



groove. It begins at the costal tuberosity and can be traced laterally as far as the coracoid tubercle, an eminence on the under aspect of the bone near the junction of prismatic and flattened portions. The **anterior border** is continuous with the anterior border of the flattened portion and separates the anterior and inferior surfaces. Medially, it forms the lower boundary of the elliptical area for the origin of the *pectoralis major*, and approaches the posterior border. Near the middle of the bone it coincides with the anterior lip of the subclavian groove.

Flattened portion.—The lateral third of the bone, extending from a point opposite the coracoid process of the scapula to the acromial extremity, is flat-

FIG. 169.—THE LEFT CLAVICLE. (Inferior surface.)



tened from above downward and presents two surfaces and two borders. The **superior surface** is rough and looks directly upward and gives attachment to the *trapezius* behind and the *deltoid* in front; between the two areas the surface is subcutaneous. On the **inferior surface,** near the posterior border, is a rough elevation, the **coracoid** (conoid) **tubercle;** it overhangs the coracoid process and gives attachment to the conoid ligament. From the coracoid tubercle, a prominent ridge, the **trapezoid** or **oblique line,** runs laterally and forward to near the lateral end of the bone. To it the trapezoid ligament is attached. The conoid and trapezoid ligaments are the two parts of the coraco-clavicular ligament which binds the clavicle down to the coracoid process.

The **anterior border** is sharp, gives origin to the *deltoid* muscle, and frequently presents near the junction of the flattened and prismatic portions a projection known as the **deltoid tubercle.** The **posterior border** is thick and rounded, and receives the insertion of the upper fibres of the *trapezius.*

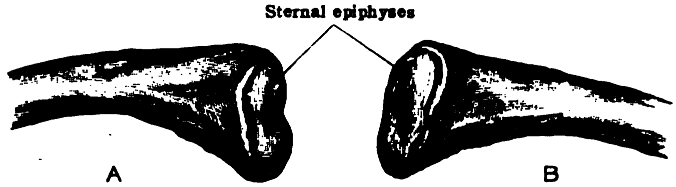
Extremities.—The **sternal extremity** of the clavicle presents a triangular articular surface, directed medially, downward, and a little forward, slightly concave from before backward and convex from above downward, which articulates with a facet on the upper border of the manubrium sterni through an interposed interarticular fibro-cartilage.

Of the three angles, one is above and two below. The *postero-inferior angle* is prolonged backward, and so renders this surface considerably larger than that with which it articulates; the *superior angle* receives the attachment of the upper part of the fibro-cartilage. The lower part of the surface is continuous with a facet on the under aspect of the bone, medial to the costal tuberosity, for the first costal cartilage. The circumference of the extremity is rough, and gives attachment to the interclavicular ligament above and the anterior and posterior sterno-clavicular ligaments in front and behind.

The **acromial extremity** presents a smooth, oval, articular facet, flattened or convex, directed slightly downward for the acromion; its border is rough, for the attachment of the capsule of the acromio-clavicular joint.

Structure.—The clavicle consists externally of a compact layer of bone, much thicker in the middle and thinning out gradually toward the two extremities. There is no true medullary

FIG. 170.—THE STERNAL ENDS OF TWO CLAVICLES WITH EPIPHYSES.
A, right clavicle from below and behind. B, left clavicle from below and behind.
(From Royal College of Surgeons Museum.)



cavity, for the interior is occupied from end to end by cancellous tissue, the amount in the various parts of the bone being in inverse proportion to the thickness of the outer compact shell

Ossification.—From observations made by F. P. Mall, D. C. L. Fitzwilliams, and E. Fawcett it seems almost certain that there are two centres of ossification of the shaft of the clavicle, at the juncture of the middle and lateral thirds. They appear very early, about the fifth week of embryonic life, and rapidly fuse. The ossific process extends medially and laterally along the shaft toward the medial and lateral extremities, respectively. About the eighteenth year a secondary centre appears at the sternal end and forms a small epiphysis which joins the shaft about the twenty-fifth year.

THE SCAPULA

The **scapula** (figs. 171, 172) is a large flat bone, triangular in shape, situated on the dorsal aspect of the thorax, between the levels of the second and seventh ribs. Attached to the trunk by means of the clavicle and various muscles it articulates with the lateral end of the clavicle at the acromio-clavicular joint, and with the humerus at the shoulder-joint. The greater part of the bone consists of a triangular plate known as the *body*, from which two processes are prolonged: one anterior in position, is the *coracoid;* the other, posterior in position, is the *spine*, which is continued laterally into the *acromion.*

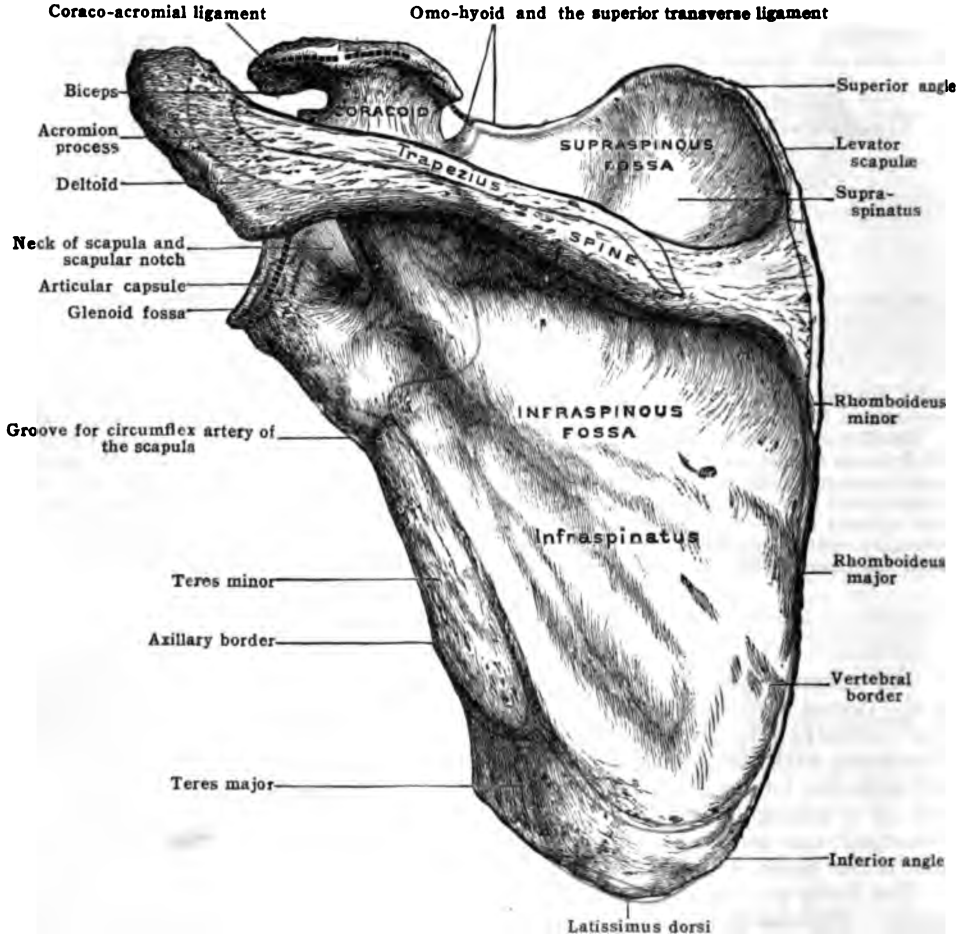
The body presents for examination two surfaces, three borders, and three angles. The **costal** (anterior) **surface,** or venter, looks considerably medialward, is deeply concave, forming the **subscapular fossa,** and marked by several oblique lines which commence at the posterior border and pass obliquely upward and laterally; these lines or ridges divide the surface into several shallow grooves, from which the *subscapularis* takes origin, whilst the ridges give attachment to the tendinous intersections of that muscle. The lateral third of the surface is smooth and overlapped by the subscapularis, whilst medially are two small flat areas in front of the upper and lower angles respectively, but excluded from the subscapular fossa by fairly definite lines and joined by a ridge which runs close to the vertebral border. The ridge and its terminal areas serve for the insertion of the *serratus anterior* (*magnus*).

The **dorsal** (posterior) **surface** is generally convex and divided by a prominent plate of bone—the **spine**—into two unequal parts. The hollow above the spine is the **supraspinous fossa** and lodges the *supraspinatus* muscle. The part below

the spine is the **infraspinous fossa**; it is three times as large as the supraspinous fossa, is alternately concave and convex, and gives origin to the *infraspinatus*. The muscle is attached to its medial three-fourths and covers the lateral fourth, without taking origin from it.

The infraspinous fossa does not extend as far as the axillary border, but is limited laterally by a ridge—**the oblique line**—Which runs from the glenoid cavity—the large articular surface for the head of the humerus—downward and backward to join the posterior border a short distance above the inferior angle. This line, which gives attachment to a stout aponeurosis, cuts off an elongated surface, narrow above for the origin of the *teres minor*, and crossed near its middle by a groove for the circumflex (dorsal) artery of the scapula; below, the surface is broader for the origin of the *teres major* and occasionally a few fibres of the *latissimus dorsi*. The two areas are separated by a line which gives attachment to an aponeurotic septum situated between the two teres muscles.

FIG. 171.—THE LEFT SCAPULA. (Dorsal surface.)



The supra- and infraspinous fossæ communicate through the **great scapular notch** at the lateral border of the spine, and through the notch the suprascapular nerve and transverse scapular artery are transmitted from one fossa to the other.

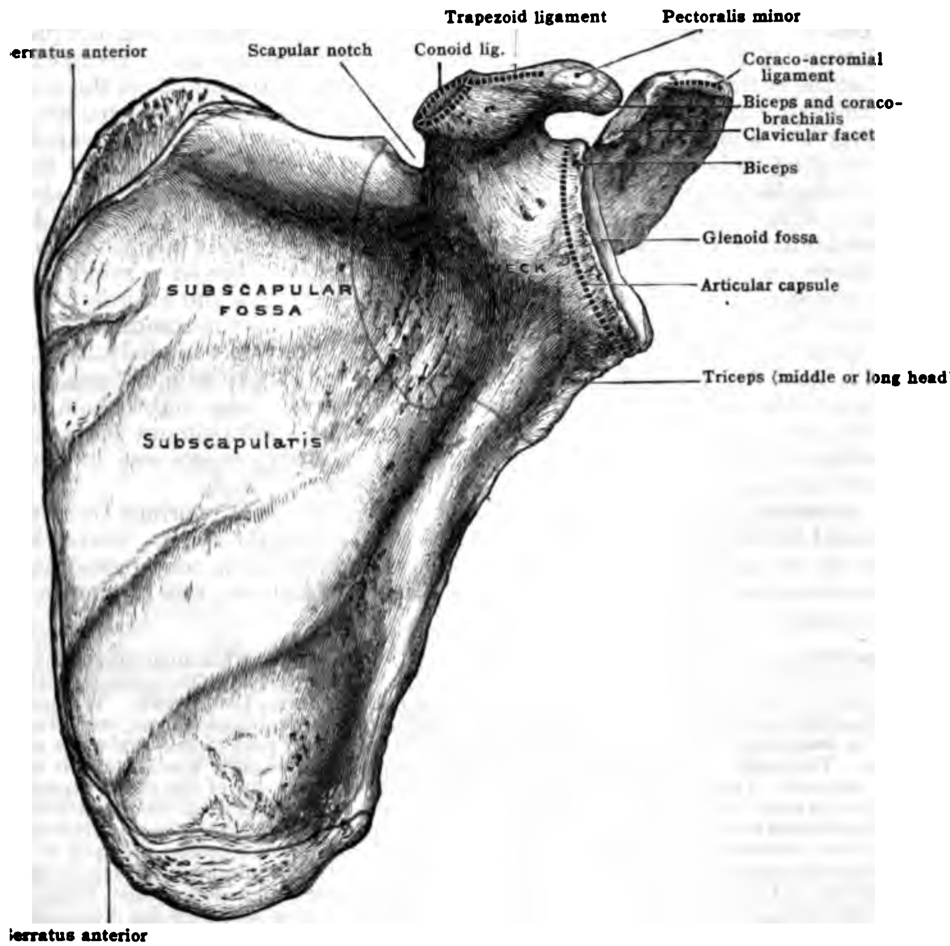
Borders.—The three borders of the scapula are named superior, vertebral, and axillary. The **superior** is short and thin and extends from the upper angle to the coracoid process. Laterally it presents a deep depression, the **scapular notch,** to the extremities of which the superior transverse ligament is attached.

Not infrequently the notch is replaced by a **scapular foramen**, and it is interesting to note that a bony foramen occurs normally in some animals, notably the great ant-eater (*Myrmecophaga jubata*). The notch or foramen transmits the suprascapular nerve, whilst the transverse scapular artery usually passes over the ligament. From the adjacent margins of the notch and from the ligament the posterior belly of the *omo-hyoid* takes origin.

The **vertebral border** (sometimes called the base) is the longest, and extends rom the upper or medial to the lower angle of the bone. It is divisible into three ›arts, to each of which a muscle is attached: an upper portion, extending from he medial (superior) angle to the spine, for the insertion of the *levator scapulæ;* . middle portion, opposite the smooth triangular area at the commencement ›f the spine, for the *rhomboideus minor;* and the lowest and longest portion, xtending below this as far as the inferior angle, for the *rhomboideus major,* he attachment of which takes place through the medium of a fibrous arch.

The **axillary border** is the thickest, and extends from the lower margin of he glenoid cavity to the inferior angle of the bone. Near its junction with the ;lenoid cavity there is a rough surface, about 2.5 cm. (1 in.) in length the in-**raglenoid tubercle,** from which the long head of the *triceps* arises, and below

FIG. 172.—THE LEFT SCAPULA. (Ventral surface.)



he tubercle is the groove for the circumflex (dorsal) artery of the scapula. The upper two-thirds of the border is deeply grooved on the ventral aspect and ;ives origin to a considerable part of the *subscapularis.*

Angles.—The three angles are named medial, inferior, and lateral.

The medial (or superior) **angle,** forming the highest part of the body, is thin, smooth, and ither rounded or approximating a right angle. It is formed by the junction of the superior nd vertebral borders and gives insertion to a few fibres of the *levator scapulæ.* **The inferior ngle,** constituting the lowest part of the body, is thick, rounded, and rough. It is formed by he junction of axillary and vertebral borders, gives origin to the *teres major,* and is crossed orizontally by the upper part of the *latissimus dorsi,* the latter occasionally receiving from it small slip of fleshy fibres.

The lateral angle forms the expanded portion of the bone known as the **head,** earing the **glenoid cavity,** and supported by a somewhat constricted **neck.** The

glenoid cavity is a wide, shallow, pyriform, articular surface for the head of the humerus, directed forward and laterally, with the apex above and the broad end below. Its margin is raised, and affords attachment to the glenoid ligament, which deepens its concavity. The margin is not, however, of equal prominence throughout, being somewhat defective where it is overarched by the acromion, notched anteriorly, and emphasised above to form a small eminence, the **supraglenoid tubercle,** for the attachment of the long head of the *biceps*.

The circumference and adjoining part of the neck give attachment to the articular capsule of the shoulder-joint, and the anterior border to the three accessory ligaments of the capsule, known as the superior, middle, and inferior gleno-humeral folds. The superior fold (Flood's ligament) is attached above the notch near the upper end; of the two remaining folds, which together constitute Schlemm's ligament, the middle is attached immediately above the notch and the inferior below the notch. In the recent state the glenoid fossa is covered with hyaline cartilage. The **neck** is more prominent behind than before and below than above, where it supports the coracoid process. It is not separated by any definite boundary from the body.

Processes.—The **spine** is a strong, triangular plate of bone attached obliquely to the dorsum of the scapula and directed backward and upward. Its apex is situated at the vertebral border; the base, corresponding to the middle of the neck, is free, concave, and gives attachment to the inferior transverse ligament, which arches over the transverse scapular (suprascapular) vessels and suprascapular nerve. Of the two borders, one is joined to the body, whilst the other is free, forming a prominent subcutaneous **crest.** The latter commences at the vertebral border, in a smooth triangular area, over which the tendon of the *trapezius* glides, usually without the intervention of a bursa, as it passes to its insertion into a small tubercle on the crest beyond. Further laterally, this border is rough, and presents two lips—a superior for the insertion of the *trapezius* and an inferior for the origin of the *deltoid*. Laterally the crest is continued into the **acromion.**

The **spine** has two surfaces, the superior, which also looks medialward and forward, is concave, contributes to the formation of the supraspinous fossa, and gives origin to the *supraspinatus* muscle; the inferior surface, also slightly concave, is directed lateralward and backward, forms part of the infraspinous fossa, and affords origin to the *infraspinatus* muscle. On both surfaces are one or more prominent vascular foramina.

The **acromion,** a process overhanging the glenoid cavity, springs from the angle formed by the junction of the crest with the base of the spine. Somewhat crescentic in shape, it forms the summit of the shoulder and is compressed from above downward so as to present for examination two surfaces, two borders, and two extremities.

The posterior part sometimes terminates laterally in a prominent **acromial angle** (metacromion) and the process then assumes a more or less triangular form. Of the two extremities, the posterior is continuous with the spine, whilst the anterior forms the free tip. The upper surface, directed upward, backward, and slightly lateralward, is rough and convex, and affords origin at its lateral part to a portion of the *deltoid;* the remaining part of this surface is subcutaneous. The lower surface, directed downward, forward, and slightly medialward, is concave and smooth. The medial border, continuous with the upper lip of the crest, presents, from behind forward, an area for the insertion of the *trapezius;* a small, oval, concave articular facet for the lateral end of the clavicle, the edges of which are rough for the acromio-clavicular ligaments; and, beyond this, the anterior extremity or tip, to which is attached the apex of the coraco-acromial ligament. The lateral border, continuous with the inferior lip of the crest, is thick, convex, and presents three or four tubercles with intervening depressions; from the tubercles the tendinous septa in the acromial part of the *deltoid* arise, and from the depressions, some fleshy fibres of the same muscle.

Projecting upward from the neck of the scapula is the **coracoid process,** bent finger-like, pointing forward and laterally. It consists of two parts, ascending and horizontal, arranged at almost a right angle to each other.

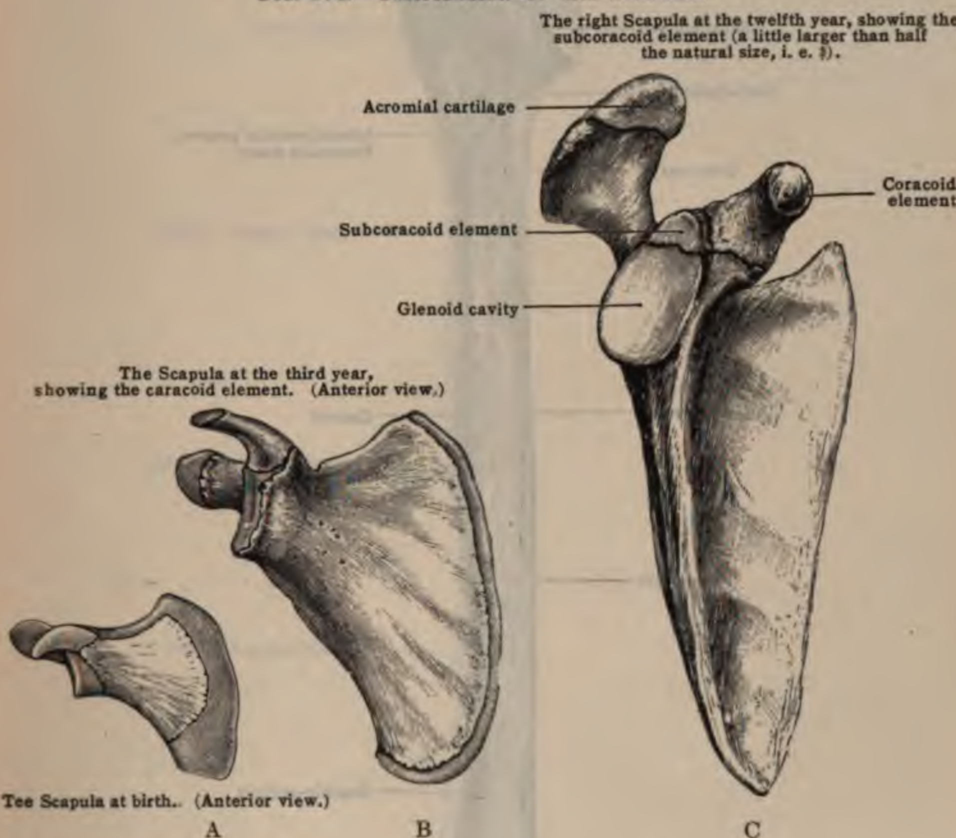
The *ascending part* arises by a wide root, extends upward and medially for a short distance, and is compressed from before backward; it is continuous above with the horizontal part and below with the neck of the scapula; the lateral border lies above the glenoid cavity and gives attachment to the coraco-humeral ligament; the medial border, which forms the lateral boundary of the scapular notch, gives attachment to the conoid ligament above and the transverse ligament below. Its anterior and posterior surfaces are in relation with the *subscapularis* and *supraspinatus* respectively. The *horizontal part* of the process runs forward and lateralward; it is compressed from above downward so as to present two borders, two surfaces, and a free extremity. The medial border gives insertion along its anterior half to the *pectoralis minor* and nearer the base to the costo-coracoid membrane; the lateral border is rough for the coraco-acromial and coraco-humeral ligaments; the upper surface is irregular and gives insertion in

front to the *pectoralis minor*, and behind to the trapezoid ligament; the inferior surface is smooth and directed toward the glenoid cavity, which it overhangs; the free extremity or apex gives origin to the conjoined *coraco-brachialis* and short head of the *biceps*.

The greater part of the body of the scapula and the central parts of the spinous process are thin and transparent. The coracoid and acromion processes, the crest of the spine and inferior angle, the head, neck, and axillary border, are thick and opaque. The young bone consists of two layers of compact tissue with an intervening cancellous layer, but in the transparent parts of the adult bone the middle layer has disappeared. The vascular foramina on the costal surface transmit twigs from the subscapular and transverse scapular (suprascapular) arteries; those in the infraspinous fossa, twigs from the circumflex (dorsal) and transverse scapular (suprascapular) arteries, the latter also giving off vessels which enter the foramina in the supraspinous fossa. The acromion is supplied by branches from the thoraco-acromial (acromio-thoracic) artery.

The line of attachment of the spinous process to the dorsum of the scapula is known as the **morphological axis,** and the obtuse angle in the subscapular fossa opposite the spine as the

FIG. 173.—OSSIFICATION OF THE SCAPULA.



subscapular angle. From the axis three plates of bone radiate as from a centre, the **prescapula** forward, the **mesoscapula** laterally, and the **postscapula** backward, being named in accordance with the long axis of the body in the horizontal position. In the human subject the postscapula is greatly developed, and this is associated with the freedom and versatility of movement possessed by the upper limb.

Ossification.—The scapula is ossified from nine centres. Of these, two (for the body of the scapula and the coracoid) may be considered as **primary,** and the remainder as **secondary.** The centre for the body appears in a plate of cartilage near the neck of the scapula about the eighth week of intra-uterine life, and quickly forms a triangular plate of bone, from which the spine appears as a slight ridge about the middle of the third month. At birth the glenoid fossa and part of the scapular neck, the acromion and coracoid processes, the vertebral border and inferior angle, are cartilaginous. During the first year a nucleus appears for the coracoid, and at the tenth year a second centre appears for the base of the coracoid and the upper part of the glenoid cavity (subcoracoid, fig. 173).

During the fifteenth year the coracoid unites with the scapula, and about this time the other secondary centres appear. Two nuclei are deposited in the acromial cartilage, and fuse to form the acromion, which joins the spine at the twentieth year. The union of spine and acromion may be fibrous, hence the latter is sometimes found separate in macerated specimens. The cartilage along the vertebral border ossifies from two centres, one in the middle, and another at the inferior angle. A thin lamina is added along the upper surface of the coracoid process and

glenoid cavity is a wide, shallow, pyriform, articular surface for the head of the humerus, directed forward and laterally, with the apex above and the broad end below. Its margin is raised, and affords attachment to the glenoid ligament, which deepens its concavity. The margin is not, however, of equal prominence throughout, being somewhat defective where it is overarched by the acromion, notched anteriorly, and emphasised above to form a small eminence, the **supraglenoid tubercle,** for the attachment of the long head of the *biceps*.

The circumference and adjoining part of the neck give attachment to the articular capsule of the shoulder-joint, and the anterior border to the three accessory ligaments of the capsule, known as the superior, middle, and inferior gleno-humeral folds. The superior fold (Flood's ligament) is attached above the notch near the upper end; of the two remaining folds, which together constitute Schlemm's ligament, the middle is attached immediately above the notch and the inferior below the notch. In the recent state the glenoid fossa is covered with hyaline cartilage. The **neck** is more prominent behind than before and below than above, where it supports the coracoid process. It is not separated by any definite boundary from the body.

Processes.—The **spine** is a strong, triangular plate of bone attached obliquely to the dorsum of the scapula and directed backward and upward. Its **apex** is situated at the vertebral border; the base, corresponding to the middle of the neck, is free, concave, and gives attachment to the inferior transverse ligament, which arches over the transverse scapular (suprascapular) vessels and suprascapular nerve. Of the two borders, one is joined to the body, whilst the other is free, forming a prominent subcutaneous **crest.** The latter commences at the vertebral border, in a smooth triangular area, over which the tendon of the *trapezius* glides, usually without the intervention of a bursa, as it passes to its insertion into a small tubercle on the crest beyond. Further laterally, this border is rough, and presents two lips—a superior for the insertion of the *trapezius* and an inferior for the origin of the *deltoid*. Laterally the crest is continued into the **acromion.**

The **spine** has two surfaces, the superior, which also looks medialward and forward, is concave, contributes to the formation of the supraspinous fossa, and gives origin to the *supraspinatus* muscle; the inferior surface, also slightly concave, is directed lateralward and backward, forms part of the infraspinous fossa, and affords origin to the *infraspinatus* muscle. On both surfaces are one or more prominent vascular foramina.

The **acromion,** a process overhanging the glenoid cavity, springs from the angle formed by the junction of the crest with the base of the spine. Somewhat crescentic in shape, it forms the summit of the shoulder and is compressed from above downward so as to present for examination two surfaces, two borders, and two extremities.

The posterior part sometimes terminates laterally in a prominent **acromial angle** (metacromion) and the process then assumes a more or less triangular form. Of the two **extremities,** the posterior is continuous with the spine, whilst the anterior forms the free tip. The upper surface, directed upward, backward, and slightly lateralward, is rough and convex, and affords origin at its lateral part to a portion of the *deltoid;* the remaining part of this surface is subcutaneous. The lower surface, directed downward, forward, and slightly medialward, is concave and smooth. The medial border, continuous with the upper lip of the crest, presents, from behind forward, an area for the insertion of the *trapezius;* a small, oval, concave articular facet for the lateral end of the clavicle, the edges of which are rough for the acromio-clavicular ligaments; and, beyond this, the anterior extremity or tip, to which is attached the apex of the coraco-acromial ligament. The lateral border, continuous with the inferior lip of the crest, is thick, convex, and presents three or four tubercles with intervening depressions; from the tubercles the tendinous septa in the acromial part of the *deltoid* arise, and from the depressions, some fleshy fibres of the same muscle.

Projecting upward from the neck of the scapula is the **coracoid process,** bent finger-like, pointing forward and laterally. It consists of two parts, ascending and horizontal, arranged at almost a right angle to each other.

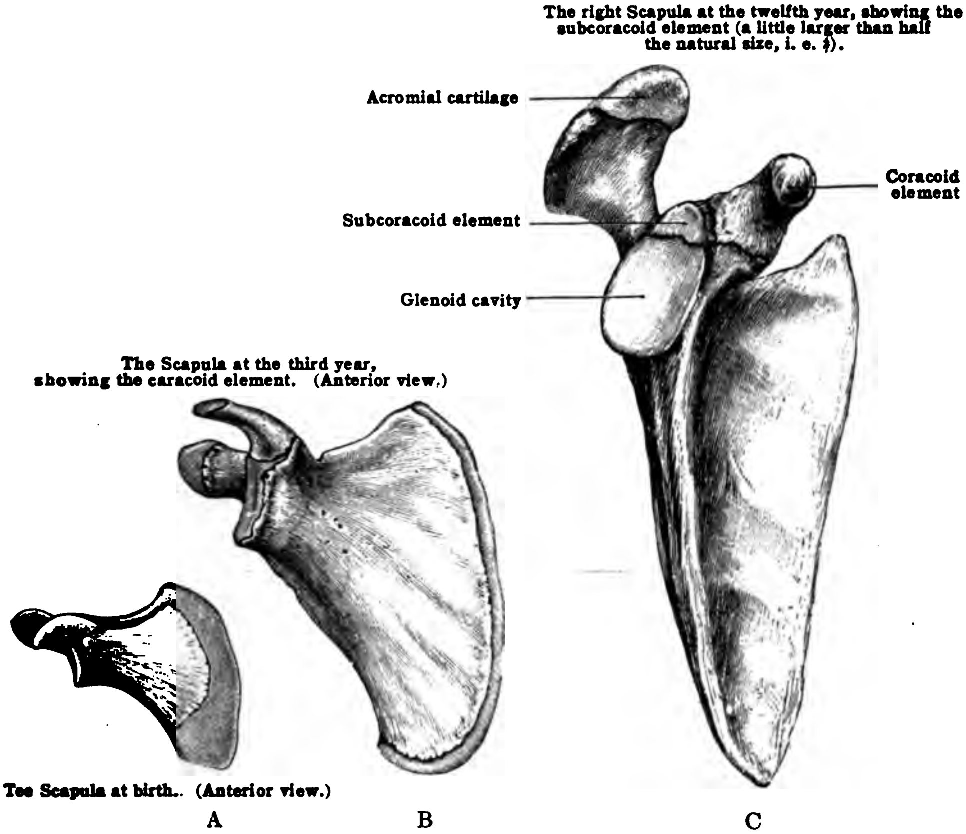
The *ascending part* arises by a wide root, extends upward and medially for a short distance, and is compressed from before backward; it is continuous above with the horizontal part and below with the neck of the scapula; the lateral border lies above the glenoid cavity and gives attachment to the coraco-humeral ligament; the medial border, which forms the lateral boundary of the scapular notch, gives attachment to the conoid ligament above and the transverse ligament below. Its anterior and posterior surfaces are in relation with the *subscapularis* and *supraspinatus* respectively. The *horizontal part* of the process runs forward and lateralward; it is compressed from above downward so as to present two borders, two surfaces, and a free extremity. The medial border gives insertion along its anterior half to the *pectoralis minor* and nearer the base to the costo-coracoid membrane; the lateral border is rough for the coraco-acromial and coraco-humeral ligaments; the upper surface is irregular and gives insertion in

front to the *pectoralis minor*, and behind to the trapezoid ligament; the inferior surface is smooth and directed toward the glenoid cavity, which it overhangs; the free extremity or apex gives origin to the conjoined *coraco-brachialis* and short head of the *biceps*.

The greater part of the body of the scapula and the central parts of the spinous process are thin and transparent. The coracoid and acromion processes, the crest of the spine and inferior angle, the head, neck, and axillary border, are thick and opaque. The young bone consists of two layers of compact tissue with an intervening cancellous layer, but in the transparent parts of the adult bone the middle layer has disappeared. The vascular foramina on the costal surface transmit twigs from the subscapular and transverse scapular (suprascapular) arteries; those in the infraspinous fossa, twigs from the circumflex (dorsal) and transverse scapular (suprascapular) arteries, the latter also giving off vessels which enter the foramina in the supraspinous fossa. The acromion is supplied by branches from the thoraco-acromial (acromiothoracic) artery.

The line of attachment of the spinous process to the dorsum of the scapula is known as the **morphological axis,** and the obtuse angle in the subscapular fossa opposite the spine as the

Fig. 173.—Ossification of the Scapula.



subscapular angle. From the axis three plates of bone radiate as from a centre, the **prescapula** forward, the **mesoscapula** laterally, and the **postscapula** backward, being named in accordance with the long axis of the body in the horizontal position. In the human subject the postscapula is greatly developed, and this is associated with the freedom and versatility of movement possessed by the upper limb.

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During the fifteenth year the coracoid unites with the scapula, and about this time the other secondary centres appear. Two nuclei are deposited in the acromial cartilage, and fuse to form the acromion, which joins the spine at the twentieth year. The union of spine and acromion may be fibrous, hence the latter is sometimes found separate in macerated specimens. The cartilage along the vertebral border ossifies from two centres, one in the middle, and another at the inferior angle. A thin lamina is added along the upper surface of the coracoid process and

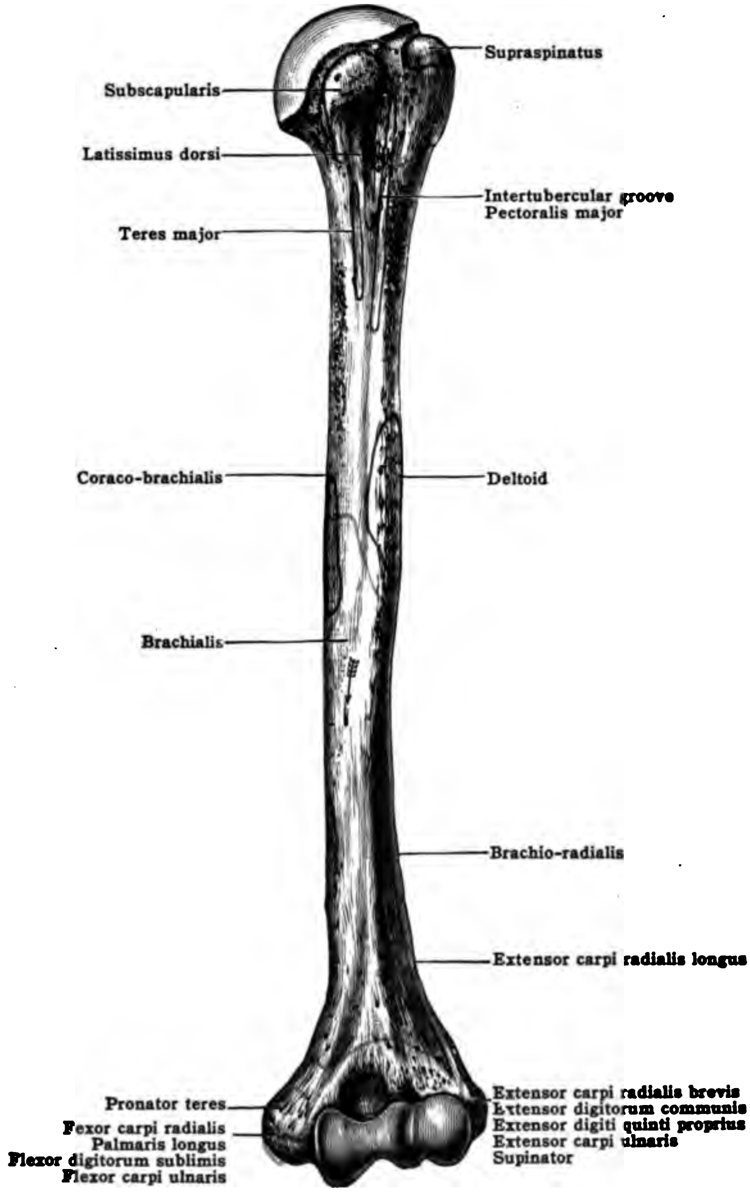
occasionally another at the margin of the glenoid cavity. These epiphyses join by the twenty-fifth year.

The occurrence of a special primary centre for the coracoid process is of morphological importance in that the process is the representative of what in the lower vertebrates is a distinct *coracoid bone.* This primarily takes part in the formation of the glenoid cavity and extends medially to articulate with the sternum. In man and all the higher mammals only the lateral portion of the bone persists.

THE HUMERUS

The **humerus** (figs. 174, 175, 176) is the longest and largest bone of the upper limb, and extends from the shoulder above, where it articulates with the scapula,

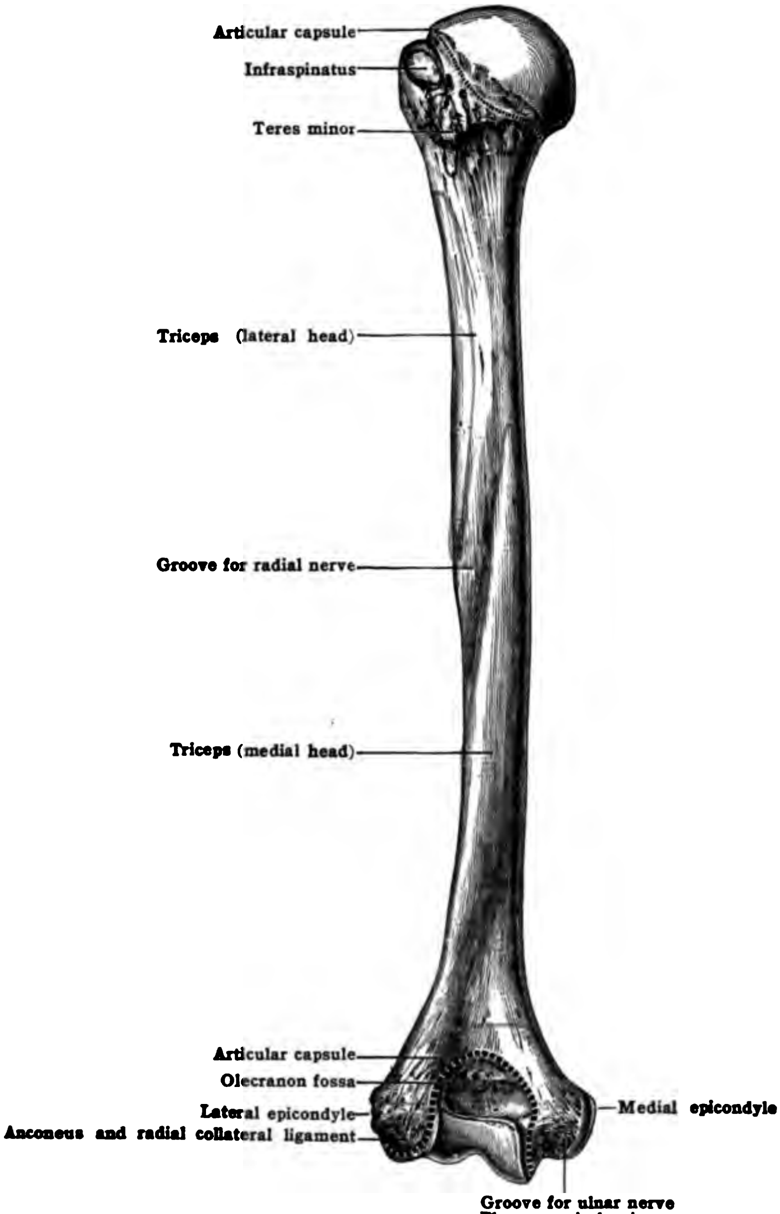
FIG. 174.—THE LEFT HUMERUS. (Anterior view.)



to the elbow [cubitus] below, where it articulates with the two bones of the forearm [anti-brachium]. It is divisible into a shaft and two extremities; the *upper* extremity includes the head [caput], neck [collum], and two tuberosities—great and small; the *lower* extremity includes the articular surface with the surmounting fossæ in front and behind, and the two epicondyles.

Upper extremity.—The **head** forms a nearly hemispherical articular surface, cartilage-clad in the recent state and directed upward, medially, and backward toward the glenoid cavity. Below the head the bone is rough and somewhat constricted, constituting the **anatomical neck,** best marked superiorly, where it forms a groove separating the articular surface from the two tuberosities. The circumference of the neck gives attachment to the capsule of the shoulder-joint and the gleno-humeral folds, the upper of which is received into a depression near the top of the intertubercular (bicipital) groove. The lowest part of the capsule

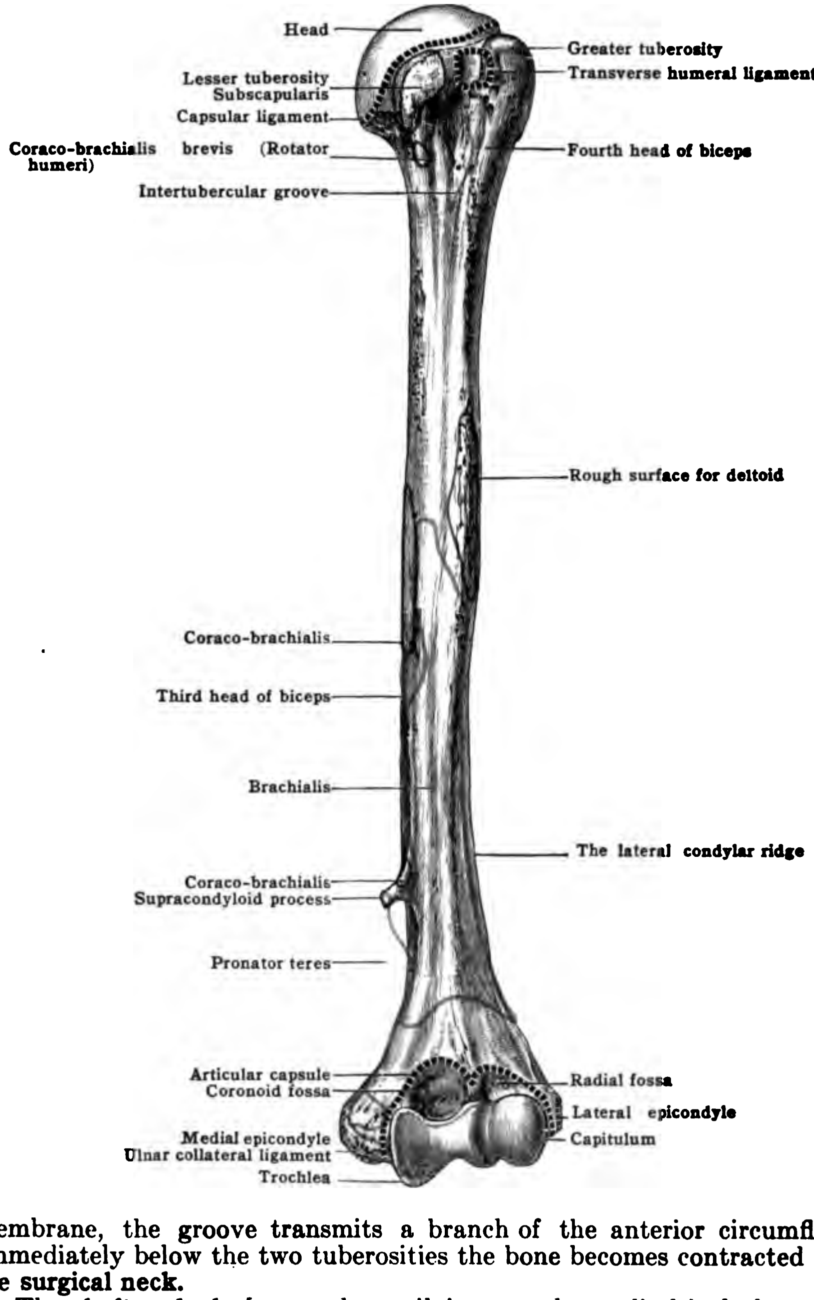
FIG. 175.—THE LEFT HUMERUS. (Posterior view.)



descends upon the humerus some distance from the articular margin. Laterally and in front of the head are the two tuberosities, separated by a deep furrow. The **greater tuberosity** [tuberculum majus], lateral in position and reaching higher than the **lesser tuberosity** [tuberculum minus], is marked by three facets for the insertion of muscles: an upper one for the *supraspinatus*, a middle for the *in-*

fraspinatus, and a lower for the *teres minor*. The **lesser tuberosity** is situated in front of the head and is the more prominent of the two; it receives the insertion of the *subscapularis*. The furrow between the tuberosities lodges the long tendon of the biceps and forms the commencement of the **intertubercular** (bicipital) **groove**, which extends downward along the shaft of the humerus. Between the tuberosities the transverse humeral ligament converts the upper end of the groove into a canal. In addition to the long tendon of the biceps and its tube of synovial

FIG. 176.—THE LEFT HUMERUS WITH A SUPRACONDYLOID PROCESS AND SOME IRREGULAR MUSCLE ATTACHMENTS. (Anterior view.)



membrane, the groove transmits a branch of the anterior circumflex artery. Immediately below the two tuberosities the bone becomes contracted and forms the **surgical neck.**

The **shaft** or **body** [corpus humeri] is somewhat cylindrical above, flattened and prismatic below. Three borders and three surfaces may be recognised.

Borders.—The **anterior border** commences above at the greater tuberosity, and its upper part, forming the **crest** of this tuberosity [crista tuberculi majoris],

receives the *pectoralis major*. In the middle of the shaft it is rough and prominent and gives insertion to fibres of the *deltoid;* below it is smooth and rounded, giving origin to fibres of the *brachialis*, and finally it passes along lateral to the coronoid fossa to become continuous with the ridge separating the capitulum and trochlea. It separates the antero-medial from the antero-lateral surface. The **lateral margin** extends from the lower and posterior part of the greater tuberosity to the lateral epicondyle. Smooth and indistinct above, it gives attachment to the *teres minor* and the lateral head of the *triceps;* it is interrupted in the middle by the **groove for the radial nerve** (musculo-spiral groove), but the lower third becomes prominent and curved laterally to form the **lateral supracondylar ridge,** which affords origin in front to the *brachio-radialis* and the *extensor carpi radialis longus;* behind to the medial head of the *triceps*, and between these muscles in front and behind to the lateral intermuscular septum. It separates the antero-lateral from the posterior surface. The **medial border** commences at the lesser tuberosity, forming its **crest** which receives the insertion of the *teres major*, and continuing downward to the medial epicondyle. Near the middle of the shaft it forms a ridge for the insertion of the *coraco-brachialis* and presents a foramen for the nutrient artery, directed downward toward the elbow-joint. Below it forms a distinct **medial supracondylar ridge,** curved medially, which gives origin to the *brachialis* in front, the medial head of the *triceps* behind, and the medial intermuscular septum in the interval between the muscles. This border separates the antero-medial from the posterior surface.

FIG. 177.—A DIAGRAM SHOWING PRESSURE AND TENSION CURVES IN THE HEAD OF THE HUMERUS. (After Wagstaffe.)

Surfaces.—The **antero-lateral surface** is smooth above, rough in the middle, forming a large impression for the insertion of the *deltoid*, below which is the termination of the groove for the radial nerve. The lower part of the surface gives origin to the lateral part of the *brachialis*. The **antero-medial surface** is narrow above, where it forms the floor of the intertubercular (bicipital) groove, and receives the insertion of the *latissimus dorsi*. Near the junction of the upper and middle thirds of the bone the groove, gradually becoming shallower, widens out and, with the exception of a rough impression near the middle of the shaft for the *coraco-brachialis*, the remaining part of the antero-medial surface is flat and smooth, and gives origin to the *brachialis*.

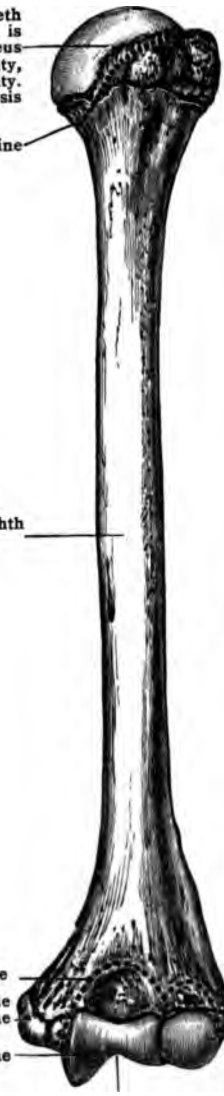
Occasionally, a prominent spine of bone, the **supracondylar process,** projects downward from the medial border about 5 cm. (2 in.) above the medial epicondyle, to which it is joined by a band of fibrous tissue. Through the ring thus formed, which corresponds to the supracondylar foraman in many of the lower animals, the median nerve and brachial artery are transmitted, though in some cases it is occupied by the nerve alone. The process gives origin to the *pronator teres*, and may afford insertion to a persistent lower part of the *coraco-brachialis*.

The **posterior surface** is obliquely divided by a broad shallow groove, which runs in a spiral direction from behind downward and forward and transmits the radial (musculo-spiral) nerve and the profunda artery. The lateral part of the surface above the groove gives attachment to the lateral head, and the part below the groove, to the medial head of the *triceps*.

The **lower extremity** of the humerus is flattened from before backward, and terminates below in a sloping articular surface, subdivided by a low ridge into the

trochlea and the **capitulum.** The **trochlea** is the pulley-like surface which extends over the end of the bone for articulation with the semilunar notch (great sigmoid cavity) of the ulna. It is constricted in the centre and expanded laterally to form two prominent edges, the medial of which is thicker, descends lower, and forms a marked projection; the lateral edge is narrow and corresponds to the interval between the ulna and radius. Above the trochlea are two fossæ: on the anterior surface is the **coronoid fossa,** an oval pit which receives the coronoid process of

FIG. 178.—OSSIFICATION OF THE HUMERUS; THE FIGURE ALSO SHOWS THE RELATIONS OF THE EPIPHYSIAL AND CAPSULAR LINES



the ulna when the forearm is flexed; on the posterior aspect is the **olecranon fossa,** a deep hollow for the reception of the anterior extremity of the olecranon in extension of the forearm. These fossæ are usually separated by a thin, translucent plate of bone, sometimes merely by fibrous tissue, so that in macerated specimens a perforation, the **supratrochlear foramen,** exists. The **capitulum,** or radial head, is much smaller than the trochlea, somewhat globular in shape, and limited to the anterior and inferior surfaces of the extremity. It articulates with the con-

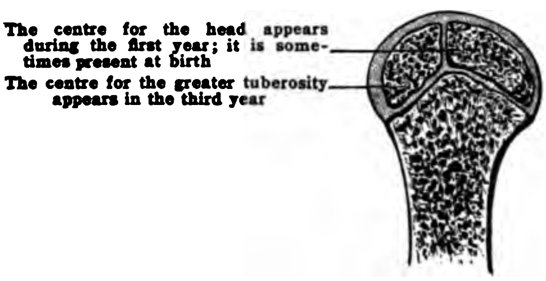
cavity on the summit of the radius. The **radial fossa** is a slight depression on the front of the bone, immediately above the capitulum, which receives the anterior edge of the head of the radius in complete flexion of the forearm, whilst between the capitulum and the trochlea is a shallow groove occupied by the medial margin of the head of the radius.

In the recent state the inferior articular surface is covered with cartilage, the fossæ are lined by synovial membrane, and their margins give attachment to the capsule of the elbow-joint. Projecting on either side from the lower end of the humerus are the two **epicondyles.** The medial one is large and by far the more prominent of the two, rough in front and below, smooth behind, where there is a shallow groove for the ulnar nerve. The rough area serves for origin of the *pronator teres* above, the common tendon of origin of the *flexor carpi radialis, palmaris longus, flexor digitorum sublimis* and *flexor carpi ulnaris* in the middle, and the ulnar collateral ligament below. The lateral epicondyle is flat and irregular. Above, it gives attachment to a common tendon of origin of the *extensor carpi radialis brevis, extensor digitorum communis, extensor quinti digiti proprius, extensor carpi ulnaris,* and *supinator;* to a depression near the outer margin of the capitulum, the radial collateral ligament is attached, and from an area below and behind, the *anconeus* takes origin.

Architecture.—The interior of the shaft of the humerus is hollowed out by a large medullary canal, whereas the extremities are composed of cancellated tissue invested by a thin compact layer. The arrangement of the cancellous tissue at the upper end of the humerus is shown in fig. 177. The lamellæ converge to the axis of the bone and form a series of superimposed arches which reach upward as far as the epiphysial line. In the epiphyses the spongy tissue forms a fine network, the lamellæ resulting from "pressure" being directed at right angles to the articular surface of the head and to the great tuberosity.

Blood-supply.—The foramina which cluster round the circumference of the head and tuberosities transmit branches from the transverse scapular (suprascapular) and anterior and posterior circumflex arteries. At the top of the intertubercular groove is a large nutrient foramen

FIG. 179.—THE HEAD OF THE HUMERUS AT THE SIXTH YEAR. (In section.)



for a branch of the anterior circumflex artery which supplies the head. The nutrient artery of the shaft is derived from the brachial, and in many cases, an additional branch, derived from the profunda artery, enters the foramen in the groove for the radial nerve (musculo-spiral groove). The lower extremity is nourished by branches derived from the profunda (superior profunda), the superior and inferior ulnar collateral (inferior profunda and anastomotic), and the recurrent branches of the radial, ulnar, and interosseous arteries.

Ossification.—The humerus is ossified from one primary centre (diaphysial) and six secondary centres (epiphysial). The centre for the shaft appears about the eighth week of intra-uterine life and grows very rapidly. At birth only the two extremities are cartilaginous, and these ossify in the following manner: Single centres appear for the head in the first year, for the greater tuberosity in the third year, and for the lesser tuberosity in the fifth year, though sometimes the latter ossifies by an extension from the greater tuberosity. These three nuclei coalesce at six years to form a single epiphysis, which joins the shaft about the twentieth year.

The inferior extremity ossifies from four centres: one for the capitulum appears in the third year, a second for the medial epicondyle in the fifth year, a third for the trochlea in the tenth year, and a fourth for the lateral epicondyle in the fourteenth year. The nuclei for the capitulum, trochlea, and lateral epicondyle coalesce to form a single epiphysis which joins the shaft in the seventeenth year. The nucleus of the medial epicondyle joins the shaft independently at the age of eighteen years.

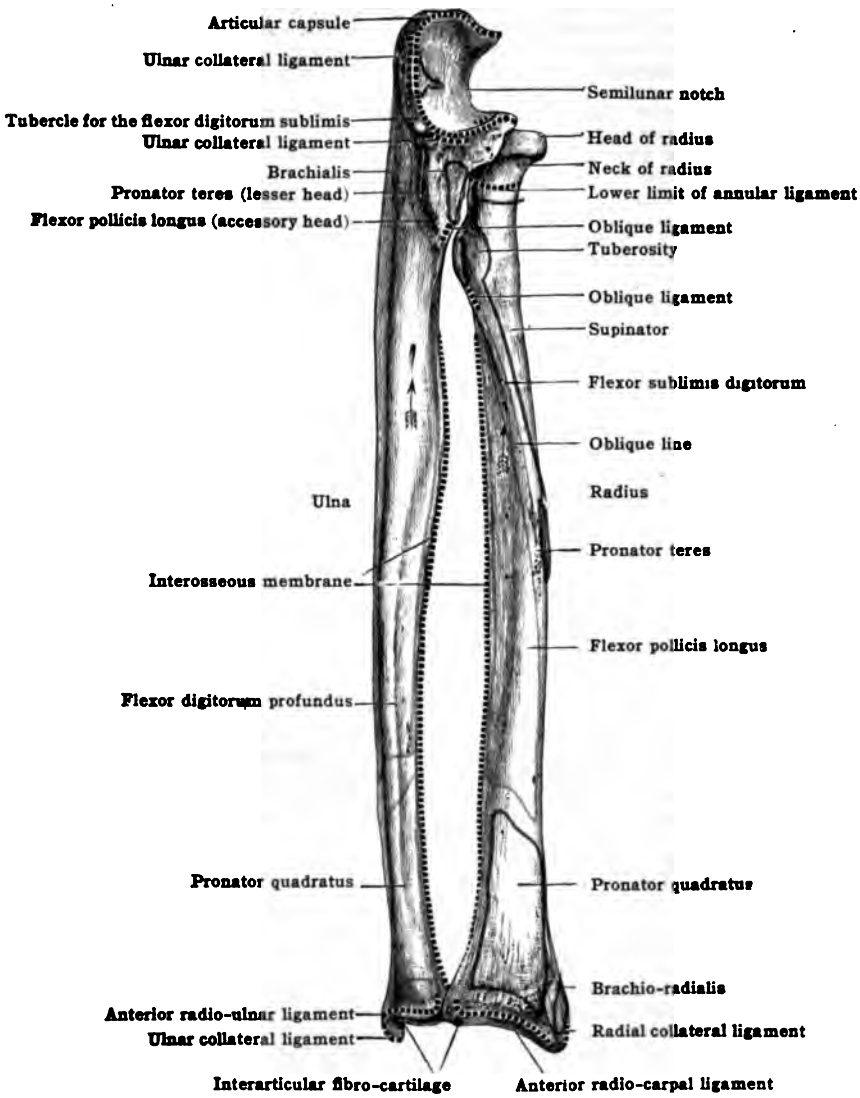
A study of the upper end of the humeral shaft before its union with the epiphysis is of interest in relation to what is known as the neck of the humerus. The term neck is applied to three parts of this bone. The *anatomical* neck is the constriction to which the articular capsule is mainly attached, and its position is accurately indicated by the groove which lies internal to the tuberosities. The upper extremity of the humeral shaft, before its union with the epiphysis, terminates in a low three-sided pyramid, the surfaces of which are separated from one another by ridges. The medial of these three surfaces underlies the head of the bone, and the two lateral surfaces underlie the tuberosities. The part supporting the head constitutes the *morphological* neck of the humerus, whilst the *surgical* neck is the indefinite area below the tuberosities where the bone is liable to fracture.

THE RADIUS

The **radius** (figs. 180–185) is the lateral and shorter of the two bones of the forearm. Above, it articulates with the humerus; below, with the carpus; and on the medial side with the ulna. It presents for examination a shaft and two extremities.

The **upper extremity,** smaller than the lower, includes the head, neck, and tuberosity. The **head** [capitulum], covered with cartilage in the recent state, is a circular disc forming the expanded, articular end of the bone. Superiorly it presents the capitular depression [fovea capituli] for the reception of the capitulum

FIG. 180.—THE LEFT ULNA AND RADIUS. (Antero-medial view.)



of the humerus; its circumference [circumferentia articularis], deeper on the medial aspect, articulates with the radial notch (lesser sigmoid cavity) of the ulna, and is narrow elsewhere for the annular ligament by which it is embraced. Below the head is a short cylindrical portion of bone, somewhat constricted, and known as the **neck.** The upper part is surrounded by the ligament which embraces the head, and below this it gives insertion antero-laterally to the *supinator.* Below the neck, at the antero-medial aspect of the bone, is an oval eminence, the radial **tuberosity,** divisible into two parts: a rough posterior portion for the insertion of

ndon of the *biceps*, and a smooth anterior surface in relation with a bursa . is situated between the tendon and the tuberosity.

ie **body** [corpus radii] or **shaft** is somewhat prismatic in form, gradually in-ng in size from the upper to the lower end, and slightly curved so as to be ve toward the ulna. Three borders and three surfaces may be recognised. e borders, the medial or **interosseous crest** [crista interossea] is best marked. nencing at the posterior edge of the tuberosity, its first part is round and in-ct, and receives the attachment of the oblique cord of the radius; it is con-

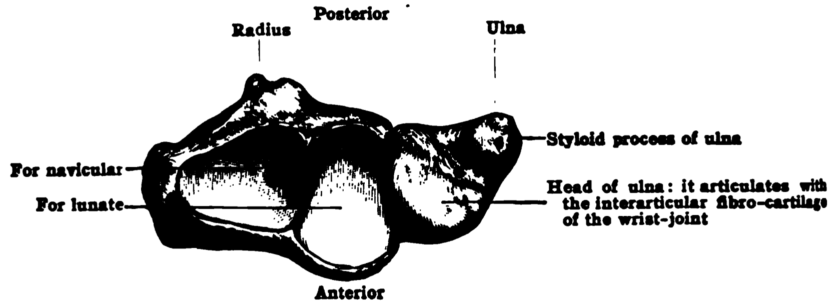
FIG. 181.—THE LEFT ULNA AND RADIUS. (Postero-lateral view.)

d as a sharp ridge which divides near the lower extremity to become continu-rith the anterior and posterior margins of the ulnar notch (sigmoid cavity). prominent ridge and the posterior of the two lower lines give attachment to nterosseous membrane, whilst the triangular surface above the ulnar notch res a part of the *pronator quadratus*. The interosseous crest separates the from the dorsal surface. The **volar border** [margo volaris] runs from the osity obliquely downward to the lateral side of the bone and then descends ally to the anterior border of the styloid process. The upper third, consti-

tuting the **oblique line** of the radius, gives origin to the radial head of the *flexor digitorum sublimis,* limits the insertion of the *supinator* above, and the origin of the *flexor pollicis longus* below. The volar border separates the volar from the lateral surface. The **dorsal border** extends from the back of the tuberosity to the prominent middle tubercle on the posterior aspect of the lower extremity. Separating the lateral from the dorsal surface, it is well marked in the middle third, but becomes indistinct above and below.

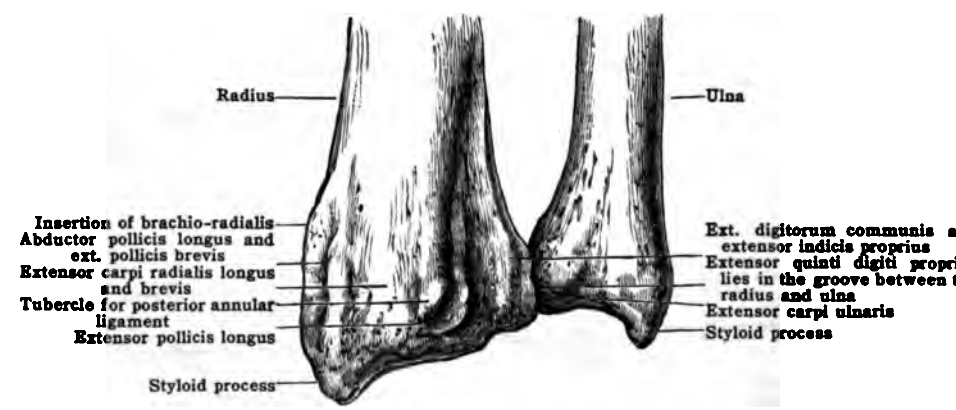
Surfaces.—The **volar** (or anterior) **surface** is narrow and concave above; broad, flat, and smooth below. The upper two-thirds is occupied chiefly by the *flexor pollicis longus* and a little less than the lower third by the *pronator quadratus.* Near

FIG. 182.—ARTICULAR FACETS ON THE LOWER END OF LEFT RADIUS AND ULNA.



the junction of the upper and middle thirds of the volar surface is the nutrient foramen, directed upward toward the proximal end of the bone. It transmits a branch of the volar interosseous artery. The **lateral surface** is rounded above and affords insertion to the *supinator;* marked near the middle by a rough, low, vertical ridge for the *pronator teres;* smooth below, where the tendons of the *extensor carpi radialis longus* and *brevis* lie upon it, and where it is crossed by the *abductor pollicis longus* and *extensor pollicis brevis.* The **dorsal** (or posterior) **surface,** smooth and rounded above, is covered by the *supinator;* grooved longitudinally in the middle third for the *abductor pollicis longus* and the *extensor pollicis*

FIG. 183.—DORSAL VIEW OF THE LOWER END OF THE RADIUS AND ULNA.



brevis; the lower third is broad, rounded, and covered by tendons. The line which forms the upper limit of the impression for the *abductor pollicis longus* is known as the **posterior oblique line.**

The **lower extremity** of the radius is quadrilateral; its **carpal surface** [facies articularis carpea] is articular and divided by a ridge into a medial quadrilateral portion, concave for articulation with the lunate bone; and a lateral triangular portion, extending onto the styloid process for articulation with the navicular (scaphoid) bone. The medial surface, also articular, presents the **ulnar notch** (sigmoid cavity) for the reception of the rounded margin of the head of the ulna. To the border separating the ulnar and carpal articular surfaces the **base** of the

articular disc is attached, and to the anterior and posterior borders, the anterior and posterior radio-ulnar ligaments respectively. The **anterior surface** is raised into a prominent area for the anterior ligament of the wrist-joint. The **lateral surface** is represented by the **styloid process,** a blunt pyramidal eminence, to the base of which the *brachio-radialis* is inserted, whilst the tip serves for the attachment of the radial (external) collateral ligament of the wrist. Its lateral surface is marked by two shallow furrows for the tendons of the *abductor pollicis longus* and *extensor pollicis brevis.* The **posterior surface** is convex, and marked by three prominent ridges separating three furrows. The posterior annular ligament is attached to these ridges, thus forming with the bone a series of tunnels for the passage of tendons.

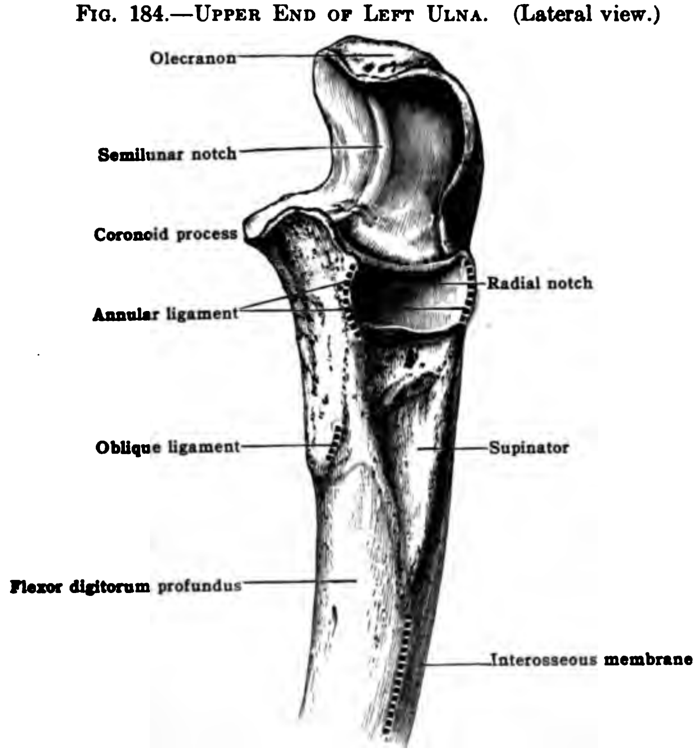
The most lateral is broad, shallow, and frequently subdivided by a low ridge. The lateral subdivision is for the *extensor carpi radialis longus,* the medial for the *extensor carpi radialis brevis.* The middle groove is narrow and deep for the tendon of the *extensor pollicis longus.* The most medial is shallow and transmits the *extensor indicis proprius,* the *extensor digitorum communis,* the dorsal branch of the interosseous artery, and the dorsal interosseous nerve. When the radius and ulna are articulated, an additional groove is formed for the tendon of the *extensor quinti digiti proprius.*

Ossification.—The radius is ossified from a centre which appears in the middle of the shaft in the eighth week of intra-uterine life and from two epiphysial centres which appear after birth. The nucleus for the lower end appears in the second year, and that for the upper end, which forms simply the disc-shaped head, in the fifth year. The head unites with the shaft at the seventeenth year, whilst the inferior epiphysis and the shaft join about the twentieth year.

THE ULNA

The **ulna** (figs. 180, 181, 189) is a long, prismatic bone, thicker above than below, on the medial side of the forearm and parallel with the radius, which it

FIG. 184.—UPPER END OF LEFT ULNA. (Lateral view.)



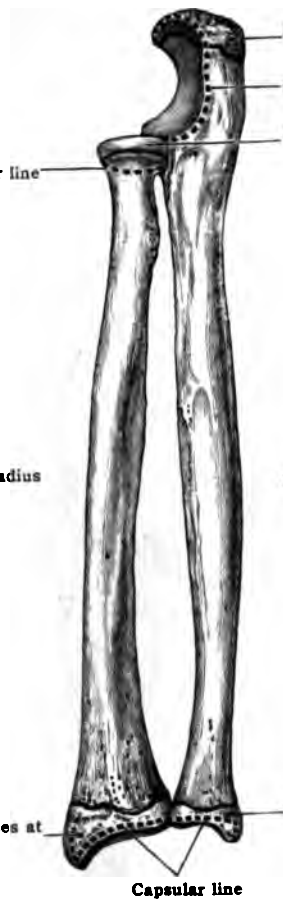
exceeds in length by the extent of the olecranon process. It articulates at the upper end with the humerus, at the lower end indirectly with the carpus, and on the lateral side with the radius. It is divisible into a shaft and two extremities.

The **upper extremity** is of irregular shape and forms the thickest and strongest part of the bone. The superior articular surface is concave from above downward, convex from side to side, and transversely constricted near the middle. It belongs

partly to the **olecranon,** the thick upward projection from the shaft, and partly to the **coronoid process,** which projects horizontally forward from the front of the ulna. This semilunar excavation forms the **semilunar notch** (greater sigmoid cavity) and articulates with the trochlear surface of the humerus. The **olecranon** is the large curved eminence forming the highest part of the bone.

The superior surface of the olecranon, uneven and somewhat quadrilateral in shape, receives behind, where there is a rough impression, the insertion of the *triceps,* and along the anterior margin the articular capsule of the elbow-joint. The posterior surface, smooth and triangular in outline, is separated from the skin by a bursa. The anterior surface, covered with cartilage in the recent state, is directed downward and forward, and its margins give attachment to the articular capsule of the elbow-joint. This surface, as already noticed, forms the upper and back part of the semilunar notch. On the medial surface of the olecranon is a tubercle for the origin of the ulnar head of the *flexor carpi ulnaris,* and in front of this a fasciculus of the ulnar collateral ligament of the elbow-joint is attached to the bone; the lateral surface is rough, concave, and gives insertion to a part of the *anconeus.* The extremity of the olecranon lies during extension of the elbow in the olecranon fossa of the humerus.

FIG. 185.—OSSIFICATION OF THE RADIUS AND ULNA; THE FIGURE ALSO SHOWS THE RELATIONS OF THE EPIPHYSIAL AND CAPSULAR LINES.



The **coronoid process,** forming the lower and anterior part of the semilunar notch, has a superior articular surface continuous with the anterior surface of the olecranon, and, like it, covered with cartilage. The inferior aspect is rough and concave, and gives insertion to the *brachialis.*

It is continuous with the volar surface of the shaft, and near the junction of the two is a rough eminence, named the **tuberosity of the ulna,** which receives the attachment of the oblique cord of the radius and the insertion of the *brachialis.* The medial side presents above a smooth tubercle for the origin of the ulnar portion of the *flexor digitorum sublimis,* and a ridge below for the lesser head of the *pronator teres* and the rounded accessory bundle of the *flexor pollicis longus,* whilst immediately behind the sublimis tubercle there is a triangular depressed surface for the upper fibres of the *flexor digitorum profundus.*

On the lateral surface is the **radial notch** (lesser sigmoid cavity), an oblong articular surface which articulates with the circumference of the head of the radius, the anterior and posterior margins of which afford attachment to the annular ligament and the radial collateral ligament of the elbow-joint. In flexion of the elbow the tip of the process is received into the coronoid fossa of the humerus.

The **body** [corpus ulnæ] or **shaft** throughout the greater part of its extent is three-sided, but tapers toward the lower extremity, where it becomes smooth and rounded. It has three borders and three surfaces. Of the three borders, the **lateral**, the **interosseous crest**, is best marked. In the middle three-fifths of the shaft it is sharp and prominent, but becomes indistinct below; above it is continued by two lines which pass to the anterior and posterior extremities of the radial notch and enclose a depressed triangular area (bicipital hollow), the fore part of which lodges the tuberosity of the radius and the insertion of the biceps tendon during pronation of the hand, while from the posterior part the *supinator* takes origin. The **interosseous crest** separates the volar from the dorsal surface and gives attachment by the lower four-fifths of its extent to the interosseous membrane. The **volar border** is directly continuous with the medial edge of the rough surface for the brachialis and terminates inferiorly in front of the styloid process.

Fig. 186.—Upper End of Ulna Showing Two Epiphyses. (E. Fawcett.)

Throughout the greater part of its extent it is smooth and rounded, and affords origin to the *flexor digitorum profundus* and the *pronator quadratus.* It separates the volar from the medial surface. The **dorsal border** commences above at the apex of the triangular subcutaneous area on the back of the olecranon, and takes a sinuous course to the back part of the styloid process. The upper three-fourths gives attachment to an aponeurosis common to three muscles, viz., the *flexor* and *extensor carpi ulnaris* and the *flexor digitorum profundus.* This border separates the medial from the dorsal surface.

Surfaces.—The **volar** (or anterior) **surface** is grooved in the upper three-fourths of its extent for the origin of the *flexor digitorum profundus,* narrow and convex below, for the origin of the *pronator quadratus.* The upper limit of the area for the latter muscle is sometimes indicated by an oblique line—the **pronator ridge.** Near the junction of the upper and middle thirds of the anterior surface is the nutrient foramen, directed upward toward the proximal end of the bone. It transmits a branch of the volar interosseous artery. The **medial surface,** smooth and rounded, gives attachment, on the upper two-thirds, to the *flexor digitorum profundus,* whereas the lower third is subcutaneous. The **dorsal** (or posterior) **surface,** directed laterally as well as backward, presents at its upper part the **oblique line** of the ulna running from the posterior extremity of the radial notch to the dorsal border.

The oblique line gives attachment to a few fibres of the *supinator* and marks off the posterior surface into two unequal parts. That above the line, much the smaller of the two, receives the insertion of the *anconeus*. The more extensive part below is subdivided by a vertical ridge into a medial portion, smooth, and covered by the *extensor carpi ulnaris*, and a lateral portion which gives origin to three muscles, viz., the *abductor pollicis longus*, the *extensor pollicis longus* and the *extensor indicis proprius*, from above downward.

The **lower extremity** of the ulna is of small size and consists of two parts, the **head** and the **styloid process,** separated from each other on the inferior surface by a groove into which the apex of the articular disc is inserted. That part of the head adjacent to the groove is semilunar in shape and plays upon the articular disc which thus excludes the ulna from the radio-carpal or wrist-joint. The margin of the head is also semilunar, and is received into the ulnar notch of the radius. The **styloid process** projects from the medial and back part of the bone, and appears as a continuation of the dorsal border. To its rounded summit the ulnar collateral ligament of the wrist-joint is attached, and its dorsal surface is grooved for the passage of the tendon of the *extensor carpi ulnaris.* Immediately above the articular margin of the head the anterior and posterior radio-ulnar ligaments are attached in front and behind.

FIG. 187.—THE LEFT RADIUS AND ULNA IN PRONATION. (Anterior view.)

Ossification.—The ulna is ossified from three centres. The primary nucleus appears near the middle of the shaft in the eighth week of intra-uterine life. At birth the inferior extremity and the greater portion of the olecranon are cartilaginous. The nucleus for the lower end appears during the fourth year and the epiphysis joins with the shaft from the eighteenth to the twentieth year. The greater part of the olecranon is ossified from the shaft, but an epiphysis is subsequently formed from a nucleus which appears in the tenth year.

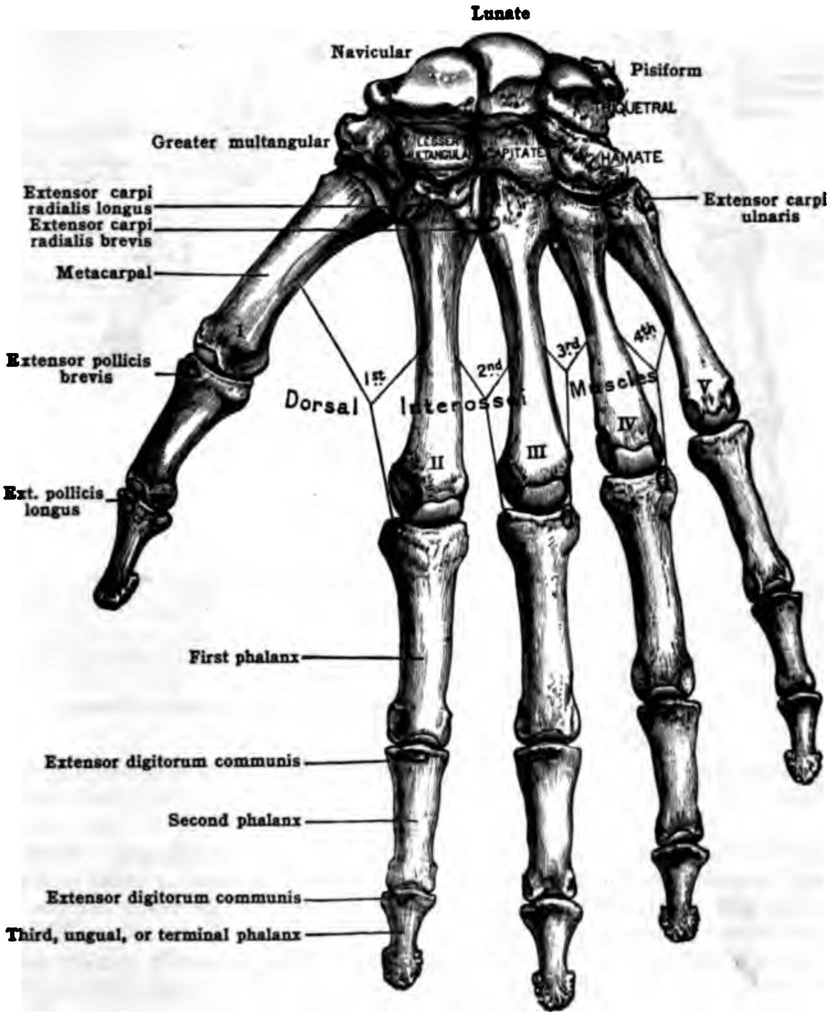
The epiphysis varies in size, and may be either scale-like and form a thin plate on the summit, or involve the upper fourth of the olecranon and the corresponding articular surface. In the latter case the epiphysis is probably composed of two parts fused together: (1) The scale on the summit of the olecranon process, and (2) the beak centre which enters into the formation of the upper end of the semilunar notch (see fig. 186). The epiphysis unites to the shaft in the sixteenth or seventeenth year.

THE CARPUS

The **carpus** (figs. 188, 189) consists of eight bones, arranged in two rows, four bones in each row. Enumerated from the radial to the ulnar side, the bones of the proximal row are named **navicular** (scaphoid), **lunate** (semilunar), **triquetral** (cuneiform), and **pisiform**; those of the distal row, **greater multangular** (trapezium), **lesser multangular** (trapezoid), **capitate** (os magnum), and **hamate** (unciform).

When the bones of the carpus are articulated, they form a mass somewhat quadrangular in outline, wider below than above, and with the long diameter transverse. The dorsal surface is convex and the volar surface concave from side to side. The concavity is increased by four prominences, which project forward, one

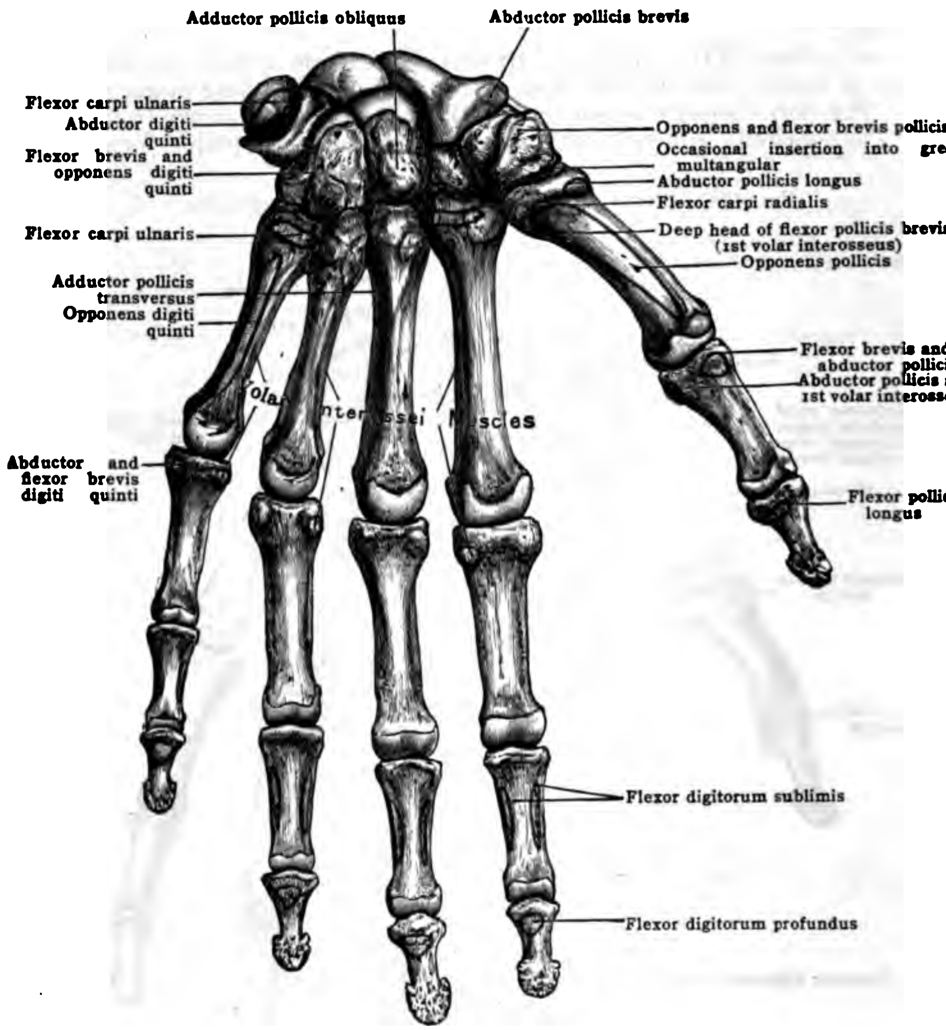
FIG. 188.—BONES OF THE LEFT HAND. (Dorsal surface.)



from each extremity of each row. On the radial side are the tuberosity of the navicular and the ridge of the greater multangular; on the ulnar side, the pisiform and the hook of the hamate. Stretched transversely between these prominences, in the recent state, is the transverse carpal ligament forming a canal for the passage of the flexor tendons and the median nerve into the palm of the hand. The proximal border of the carpus is convex and articulates with the distal end of the radius and the articular disc. The pisiform, however, takes no share in this articulation, being attached to the volar surface of the triquetral. The distal border forms an undulating articular surface for the bases of the metacarpal bones. The

line of articulation between the two rows of the carpus is concavo-convex from side to side, the lateral part of the navicular being received into the concavity formed by the greater multangular, lesser multangular, and capitate, and the capitate and hamate into that formed by the navicular, lunate, and triquetral bones.

FIG. 189.—BONES OF THE LEFT HAND. (Volar surface.)



The individual carpal bones have several points of resemblance. Each bone (excepting the pisiform) has six surfaces, of which the anterior or volar and posterior or dorsal are rough for the attachment of ligaments, the volar surface being the broader in the proximal row, the dorsal surface in the distal row. The superior and inferior surfaces are articular, the former being generally convex and the latter concave. The lateral surfaces, when in contact with adjacent bones, are also articular, but otherwise rough for the attachment of ligaments. Further, the whole of the carpus is cartilaginous at birth and each bone is ossified from a single centre.

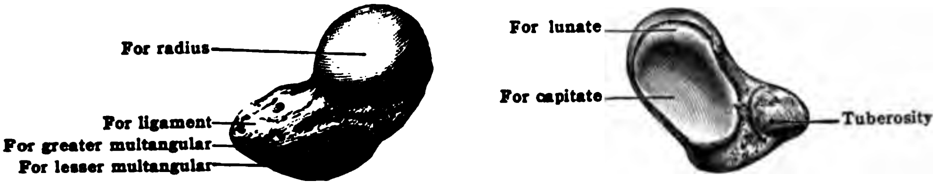
THE NAVICULAR

The **navicular** [os naviculare] or scaphoid (fig. 190) is the **largest** bone of the proximal row, and so disposed that its long axis runs obliquely downward and lateralward.

The **superior surface** is convex and somewhat triangular in shape for articulation with the lateral facet on the distal end of the radius. The **inferior surface**, smooth and convex, is divided

into two parts by a ridge running from before backward. The lateral part articulates with the greater multangular, the medial with the lesser multangular. The **volar surface**, rough and concave above, is elevated below into a prominent **tubercle** for the attachment of the transverse carpal ligament and the *abductor pollicis brevis*. The **dorsal surface** is narrow, being reduced

Fig. 190.—The Left Navicular.



to a groove running the whole length of the bone; it is rough and serves for the attachment of the dorsal radio-carpal ligament. The **medial surface** is occupied by two articular facets, of which the upper is crescentic in shape for the lunate bone, whilst the lower is deeply concave for the reception of the head of the capitate. The **lateral surface** is narrow and rough for the attachment of the radial collateral ligament of the wrist-joint.

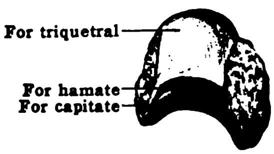
Articulations.—With the radius above, greater and lesser multangular below, lunate and capitate medially.

The Lunate

The **lunate** [os lunatum] or semilunar (fig. 191), placed in the middle of the proximal row of the carpus, is markedly crescentic in outline.

The **superior surface** is smooth and convex and articulates with the medial of the two facets on the distal end of the radius. The **inferior surface** presents a deep concavity divided into two parts by a line running from before backward. Of these, the lateral and larger articulates with the capitate; the medial and smaller with the hamate. The **volar surface** is large and convex,

Fig. 191.—The Left Lunate.



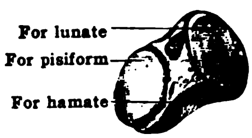
the **dorsal surface** narrow and flat, and both are rough for the attachment of ligaments. The **medial surface** is marked by a smooth quadrilateral facet for the base of the triquetral. The **lateral surface** forms a narrow crescentic articular surface for the lunate.

Articulations.—With the radius above, capitate and hamate below, navicular laterally and triquetral medially.

The Triquetral

The **triquetral** [os triquetrum] or cuneiform (fig. 192) is pyramidal in shape and placed obliquely, so that its base looks upward and laterally and the apex downward and medially.

Fig. 192.—The Left Triquetral.



The **superior surface** presents laterally near the base a small, convex articular facet which plays upon the articular disc interposed between it and the distal end of the ulna, and medially a rough non-articular portion for ligaments. The **inferior surface** forms a large, triangular undulating facet for articulation with the hamate. The **volar surface** can be readily recognised by the conspicuous oval facet near the apex for the pisiform bone. The **dorsal surface** is rough for the attachment of ligaments. The **medial** and **lateral surfaces** are represented by the base and the apex of the pyramid. The base is marked by a flat quadrilateral facet for the lunate. The **apex** forms the lowest part of the bone and is roughened for the attachment of the ulnar collateral ligament of the wrist.

Articulations.—With the pisiform in front, lunate laterally, hamate below, articular disc above.

The Pisiform

The **pisiform** [os pisiforme] (fig. 193), the smallest of the carpal bones, is in many of its characters a complete contrast to the rest of the series. It deviates from the general type in its shape, size, position, use, and development. Forming a rounded bony nodule with the long axis directed vertically, it is situated on a plane in front of the other bones of the carpus.

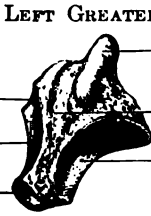
Fig. 193.—The Left Pisiform.

On the **dorsal surface** is a single articular facet for the triquetral which reaches to the upper end of the bone, but leaves a free non-articular portion below. The **volar surface**, rough and rounded, gives attachment to the transverse carpal ligament, the *flexor carpi ulnaris*, the *abductor quinti digiti*, the piso-metacarpal and the piso-hamate ligaments. The median and lateral surfaces are also rough and the lateral presents a shallow groove for the ulnar artery. It is usually considered that the pisiform is a sesamoid bone developed in the tendon of the *flexor carpi ulnaris*, though by some writers it is regarded as part of a rudimentary digit.

The Greater Multangular

The **greater multangular** [os multangulum majus] or trapezium (fig. 194), situated between the navicular and first metacarpal, is oblong in form with the lower angle prolonged downward and medially.

Fig. 194.—The Left Greater Multangular.



The **superior surface** is concave and directed upward and medially for articulation with the lateral of the two facets on the distal surface of the navicular, and on the **inferior surface** is a saddle-shaped facet for the base of the first metacarpal. The **volar surface** presents a prominent ridge with a deep groove on its medial side which transmits the tendon of the *flexor carpi radialis*. The **ridge** gives attachment to the transverse carpal ligament, the *abductor pollicis brevis*, the *opponens pollicis*, and occasionally a tendinous slip of insertion of the *abductor pollicis longus*. The **dorsal** and **lateral surfaces** are rough for ligaments. The **medial surface** is divided into two parts by a horizontal ridge. The upper and larger portion is concave and articulates with the lesser multangular; the lower—a small flat facet on the projecting lower angle—articulates with the base of the second metarcarpal.

Articulations.—With the navicular above, first metacarpal below, the lesser multangular and second metacarpal on the medial side.

The Lesser Multangular

The **lesser multangular** [os multangulum minus] or trapezoid (fig. 195), the smallest of the bones in the distal row, is somewhat wedge-shaped, with the broader end dorsally and the narrow end ventrally.

Fig. 195.—The Left Lesser Multangular.

The superior surface is marked by a small, quadrilateral, concave facet, for the media of the two facets on the lower surface of the navicular. The **inferior surface** is convex from side to side and concave from before backward, forming a saddle-shaped articular surface for the base of the second metacarpal. Of the **volar** and **dorsal surfaces**, the former is narrow and rough,

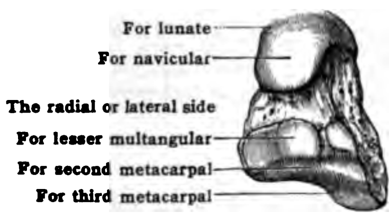
the latter broad and rounded, constituting the widest surface of the bone, and both are rough for the attachment of ligaments. The **lateral surface** slopes downward and medially and is convex for articulation with the corresponding surface of the greater multangular. On the **medial surface** in front is a smooth flat facet for the capitate; elsewhere it is rough for ligaments.

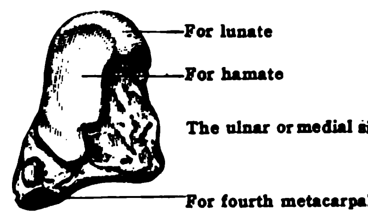
Articulations.—With the navicular above, second metacarpal below, greater multangular laterally, and the capitate medially.

The Capitate

The **capitate** [os capitatum] or os magnum (fig. 196) is the largest bone of the carpus. Situated in the centre of the wrist, the upper expanded portion, globular in shape and known as the **head,** is received into the concavity formed above by the navicular and lunate. The cubical portion below forms the **body,** whilst the intermediate constricted part is distinguished as the **neck.**

Fig. 196.—The Left Capitate.





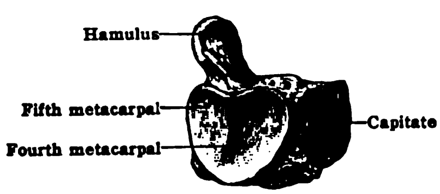
Of the six surfaces, the **superior** is smooth and convex, elongated from before backward for articulation with the concavity of the lunate bone. The **inferior surface** is divided into three unequal parts by two ridges. The middle portion, much the larger, articulates with the base of the third metacarpal; the lateral, narrow and concave, looks lateral as well as downward to articulate with the second metacarpal, whilst the medial portion is a small facet, placed on the projecting angle of the bone dorsally, for the fourth metacarpal bone. The **volar surface** is convex and rough, giving origin to fibres of the oblique *adductor pollicis;* the **dorsal surface** is broad and deeply concave. The **lateral surface** presents, from above downward:—(1) a smooth convex surface, forming the outer aspect of the head, with the superior surface of which it is continuous, for articulation with the navicular; (2) a groove representing the neck, indented for ligaments; (3) a small facet, flat and smooth, for articulation with the lesser multangular. Behind this facet is a rough area for attachment of an interosseous ligament. The **medial surface** has extending along its whole hinder margin an oblong articular surface for the hamate; the lower part of this smooth area sometimes forms a detached facet. The volar part of the surface is rough for an interosseous ligament.

Articulations.—With the lunate and navicular above, second, third, and fourth metacarpals below, lesser multangular laterally, and hamate medially.

The Hamate

The **hamate** [os hamatum] or unciform (fig. 197) is a large wedge-shaped bone, bearing a hook-like process, situated between the capitate and triquetral, with the base directed downward and resting on the two medial metacarpals.

Fig. 197.—The Left Hamate.



The apex of the wedge forms the narrow **superior surface,** directed upward and laterally for articulation with the lunate. The **inferior surface** or base is divided by a ridge into two quadrilateral facets for the fourth and fifth metacarpal bones. The **volar surface** is triangular in outline and presents at its lower part a prominent **hamulus** (unciform process), a hook-like eminence, projecting forward and curved toward the carpal canal. It is flattened from side to side so as to present two surfaces, two borders, and a free extremity. To the latter the transverse carpal ligament and the *flexor carpi ulnaris* (by means of the piso-hamate ligament) are attached, whilst the medial surface affords origin to the *flexor brevis* and the *opponens digiti quinti.* The lateral surface is concave and in relation to the flexor tendons. The **dorsal surface** is triangular and rough for ligaments. The **lateral surface** has extending along its upper and

hinder edges a long flat surface, wider above than below, for articulation with the capitate. In front of this articular facet the surface is rough for the attachment of an interosseous ligament. The **medial surface** is oblong and undulating, i. e., concavo-convex from base to apex, for articulation with the triquetral.

Articulations.—With the triquetral, lunate, capitate, and the fourth and fifth metacarpal bones.

Ossification of the Carpal Bones

Capitate	first year	Greater multangular	fifth year
Hamate	second year	Navicular	sixth year
Triquetral	third year	Lesser multangular	eighth year
Lunate	fourth year	Pisiform	twelfth year

Additional carpal elements are occasionally met with. The **os centrale** occurs normally in the carpus of many mammals, and in the human fœtus of two months it is present as a small cartilaginous nodule which soon becomes fused with the cartilage of the navicular. Failure of fusion, with subsequent ossification of the nodule, leads to the formation of an os centrale in the human carpus which is then found on the dorsal aspect, between the navicular, capitate, and lesser multangular. In most individuals, however, it coalesces with the navicular or undergoes suppression.

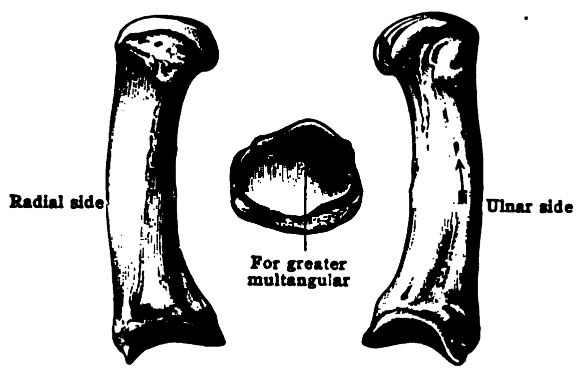
An additional centre of ossification, leading to the formation of an accessory carpal element, occasionally appears in connection with the greater multangular and the hamate. An accessory element (*os Vesalianum*) also occurs occasionally in the angle between the hamate and the fifth metacarpal, and others occur between the second and third metacarpals and the lesser multangular and capitate.

THE METACARPALS

The **metacarpus** (figs. 188, 189) consists of a series of five cylindrical bones [ossa metacarpalia], well described as 'long bones in miniature.' Articulated with the carpus above, they descend, slightly diverging from each other, to support the fingers, and are numbered from the lateral to the medial side. With the exception of the first, which in some respects resembles a phalanx, they conform to a general type.

A typical metacarpal bone presents for examination a shaft and two extremities. The **body** or **shaft** is prismatic and curved so as to be slightly convex toward the back of the hand. Of the three surfaces, two are **lateral** in position,

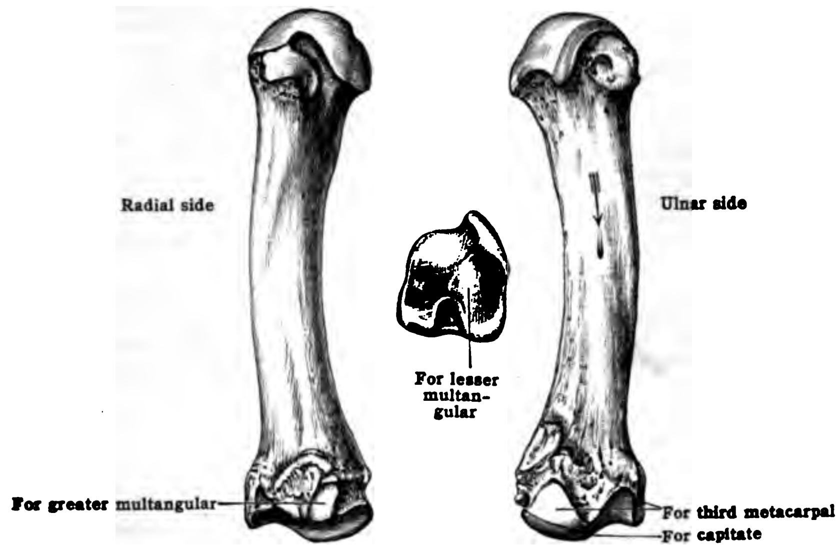
Fig. 198.—The First (Left) Metacarpal.



separated in the middle part of the shaft by a prominent palmar ridge, and concave for the attachment of *interosseous* muscles. The third or **dorsal surface** presents for examination a large, smooth, triangular area with the base below and apex above, covered in the recent state by the extensor tendons of the fingers, and two sloping areas, near the carpal extremity, also for *interosseous* muscles. The triangular area is bounded by two lines, which commence below in two dorsal tubercles, and, passing upward, converge to form a median ridge situated between the sloping areas on either side. A little above or below the middle of the shaft, and near the volar border, is the medullary foramen, entering the bone obliquely upward. The **base** or carpal **extremity**, broader behind than in front, is quadrilateral, and both palmar and dorsal surfaces are rough for **ligaments**; it articulates above with the carpus and on each side with the adjacent **metacarpal** bones. The **head** [capitulum] or digital extremity presents a large rounded articular surface, extending further on the palmar than on the dorsal **aspect, for**

articulation with the base of the first phalanx. The volar surface is grooved for the flexor tendons and raised on each side into an articular eminence. On each side of the head is a prominent tubercle, and immediately in front of this a well-marked fossa, to both of which the collateral ligament of the metacarpo-phalangeal joint is attached.

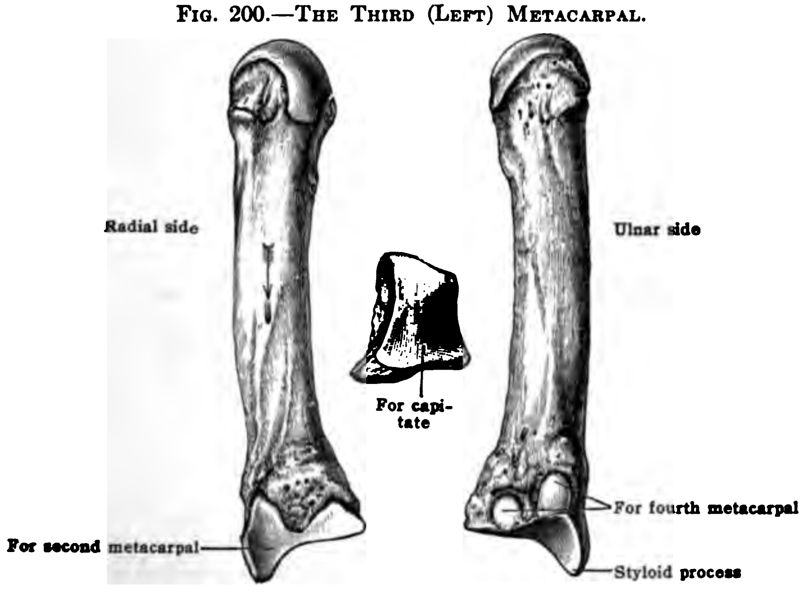
FIG. 199.—THE SECOND (LEFT) METACARPAL.



The second is the longest of all the metacarpal bones, and the third, fourth, and fifth successively decrease in length. The several metacarpals possess distinctive characters by which they are readily identified.

The **first metacarpal** (fig. 198) is the shortest and widest of the series. Diverging from the carpus more widely than any of the others the **palmar surface** is directed medially and marked

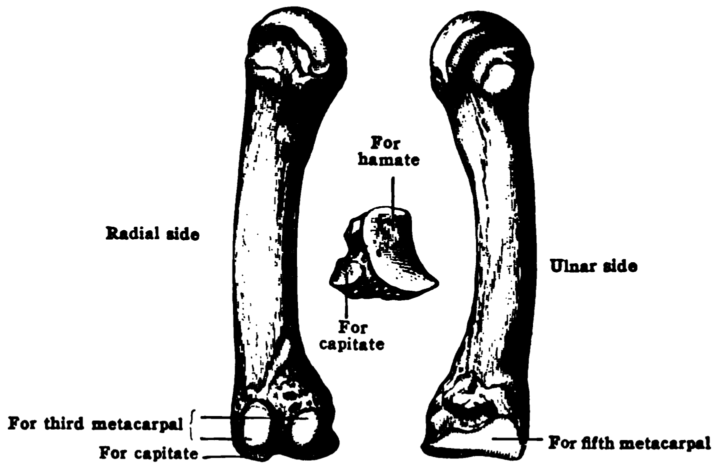
FIG. 200.—THE THIRD (LEFT) METACARPAL.



by a ridge placed nearer to the medial border. The lateral portion of the surface slopes gently to the lateral border and gives attachment to the *opponens pollicis;* the medial portion, the smaller of the two, slopes more abruptly to the medial border, is in relation to the deep head of the *flexor pollicis brevis,* and presents the nutrient foramen, directed downward toward the head of the bone and transmitting a branch of the arteria princeps pollicis. The **dorsal surface, wide and flattened,** is in relation to the tendons of the *extensor pollicis longus* and *brevis.*

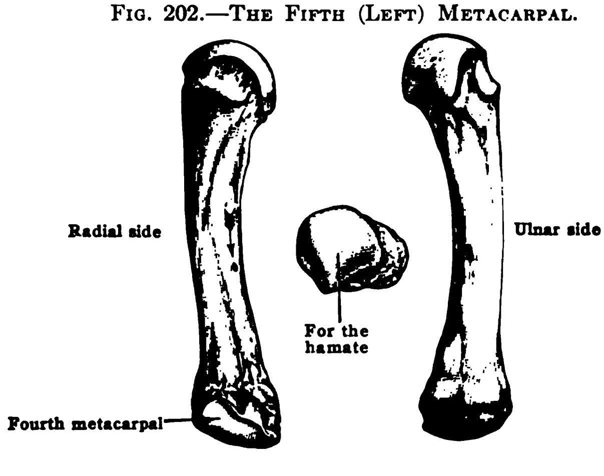
The **base** presents a saddle-shaped articular surface for the greater multangular, prolonged in front into a thin process. There are no lateral facets, but laterally a small tubercle receives the insertion of the *abductor pollicis longus*. Medially is a rough area from which fibres of the inner head of the *flexor pollicis brevis* take origin. The margin of the articular surface gives attachment to the articular capsule of the carpo-metacarpal joint. The inferior extremity or **head** is rounded and articular, for the base of the first phalanx; the greatest diameter is from side to side and the surface is less convex than the corresponding surface of the other metacarpal bones. On the volar surface it presents two articular eminences corresponding to the two sesamoid bones of the thumb. Of the two margins, the medial gives origin to the lateral head of the *first dorsal interosseous*, the lateral receives fibres of insertion of the *opponens pollicis*.

Fig. 201.—The Fourth (Left) Metacarpal.



The second metacarpal (fig. 199).—The distinctive features of the four remaining metacarpals are almost exclusively confined to the carpal extremities. The second is easily recognised by its deeply cleft base. The terminal surface presents three articular facets, arranged as follows, from lateral to medial border:—(1) a small oval facet for the greater multangular; (2) a hollow for the lesser multangular; and (3) an elongated ridge for the capitate. The dorsal surface is rough for the insertions of the *extensor carpi radialis longus* and a part of the *extensor carpi radialis brevis;* the palmar surface receives the insertion of the *flexor carpi radialis* and gives origin to a few fibres of the *oblique adductor pollicis*. The lateral aspect of the extremity is rough and non-articular; the medial surface bears a bilobed facet for the third metacarpal.

Fig. 202.—The Fifth (Left) Metacarpal.



The shaft of the second metacarpal gives attachment to three *interosseous* muscles, and the nutrient foramen, directed upward on the ulnar side, transmits a branch of the second volar metacarpal artery.

The **third metacarpal** (fig. 200) is distinguished by the prominent **styloid process** projecting upward from the lateral and posterior angle of the base. Immediately below it, on the dorsal surface, is a rough impression for the *extensor carpi radialis brevis*. The **carpal surface** is concave behind and convex in front, and articulates with the middle of the three facets on the inferior surface of the capitate. On the lateral side is a bilobed articular facet for the second metacarpal, and on the medial side two small oval facets for the fourth metacarpal. The volar spect of the base is rough and gives attachment to fibres of the *oblique adductor pollicis* and

nes a slip of insertion of the *flexor carpi radialis*. The shaft of the third metacarpal for the origin of the transverse *adductor pollicis* and two *interosseous* muscles. The t foramen is directed upward on the radial side and transmits a branch of the second ıetacarpal artery.

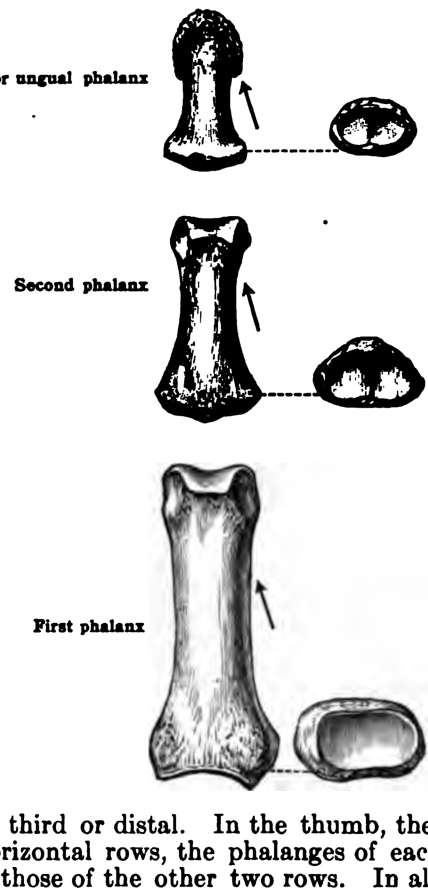
ə **fourth metacarpal** (fig. 201) has a small base. The carpal surface presents two facets: ıl, large and flat, for articulation with the hamate, and a small facet, at the lateral and ɔr angle, for the capitate. On the lateral side are two small oval facets for the correspond- ;aces on the third metacarpal and a single concave facet on the medial side for the fifth rpal. The shaft of the fourth metacarpal gives attachment to three *interosseous* muscles, ı nutrient foramen, directed upward on the radial side, transmits a branch of the third ıetacarpal artery.

ə **fifth metacarpal** (fig. 202) is distinguished by a semilunar facet on the lateral side of ə for the fourth metacarpal, and a rounded tubercle on the medial side for the *extensor lnaris*, in place of the usual medial facet. The carpal surface is saddle-shaped for the ; the palmar surface is rough for ligaments including the piso-metacarpal prolongation e *flexor carpi ulnaris*. The dorsal surface of the shaft presents an *oblique line* separating ıl concave portion for the fourth dorsal *interosseous* muscle from a smooth medial por- ʼered by the extensor tendons of the little finger. The palmar surface gives attachment y to the third palmar *interosseous* muscle and medially to the *opponens digiti quinti*. The t foramen is directed upward on the radial side and transmits a branch of the fourth ıetacarpal artery.

THE PHALANGES

e **phalanges** (fig. 203) are the bones of the fingers, and number in all fourteen. finger consists of three phalanges distinguished as first or proximal, second

ɑ. 203.—The Phalanges of the Third Digit of the Hand. (Dorsal view.)
[The arrows indicate the direction of the nutrient canals.]



ddle, and third or distal. In the thumb, the second phalanx is wanting. ged in horizontal rows, the phalanges of each row resemble one another ıffer from those of the other two rows. In all the phalanges the nutrient is directed downward, toward the distal extremity.

t **phalanx.**—The shaft of a phalanx from the first row is flat on the palmar surface, ı and rounded on the dorsal surface, i. e., semi-cylindrical in shape. The borders of the surface are rough for the attachment of the sheaths of the flexor tendons. The base acarpal extremity presents a single concave articular surface, oval in shape, for the

convex head of the metacarpal bone. The distal extremity forms a pulley-like surface, grooved in the centre and elevated at each side to form two miniature condyles, for articulation with the base of a second phalanx.

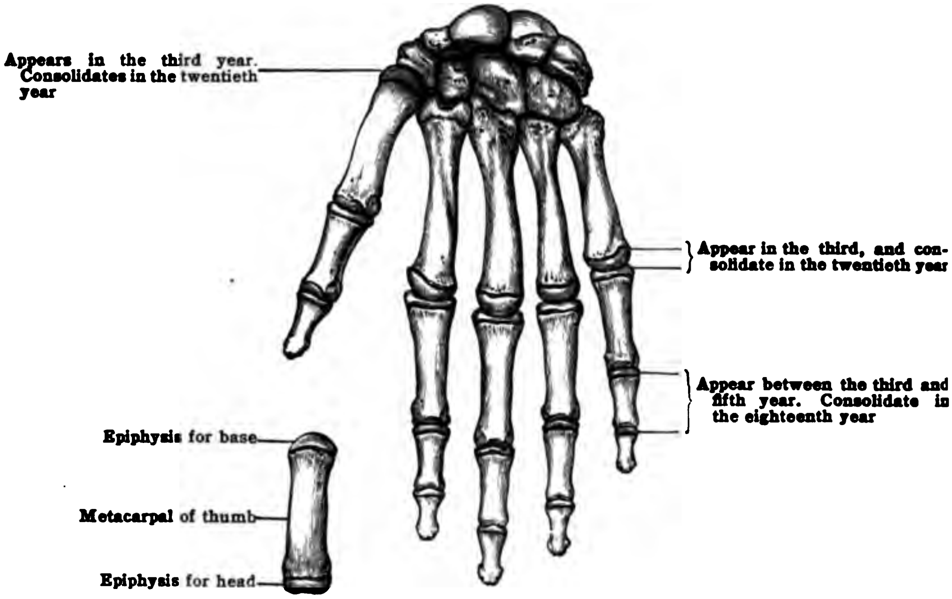
Second phalanx.—The second phalanges are four in number and are shorter than those of the first row, which they closely resemble in form. They are distinguished, however, by the articular surface on the proximal extremity, which presents two shallow depressions, separated by a ridge and corresponding to the two condyles of the first phalanx. The distal end for the base of the third phalanx is trochlear or pulley-like, but smaller than that of the first phalanx. The palmar surface of the shaft presents on each side an impression for the tendon of the *flexor digitorum sublimis*, and the dorsal aspect of the base is marked by a projection for the insertion of the *extensor digitorum communis*.

Third phalanx.—A third phalanx is readily recognised by its small size. The proximal end is identical in shape with that of a second phalanx, and bears a depression in front for the tendon of the *flexor digitorum profundus*. The free, flattened and expanded distal extremity presents on its palmar surface a rough semilunar elevation for the support of the pulp of the finger. The somewhat horseshoe-shaped free extremity is known as the **ungual tuberosity** [tuberositas unguicularis], and the bone is accordingly referred to as the **ungual phalanx.**

Ossification of the Metacarpus and Phalanges

Each of the metacarpal bones and phalanges is ossified from a primary centre for the greater part of the bone, and from one epiphysial centre. The primary nucleus appears from the eighth to the tenth week of intra-uterine life. In four metacarpal bones the epiphysis is distal, whilst

Fig. 204.—Ossification of the Metacarpals and Phalanges.



in the first metacarpal bone, and in all the phalanges, it is proximal. The epiphysial nuclei appear from the third to the fifth year and are united to their respective shafts about the twentieth year. In many cases the first metacarpal has two epiphyses, one for the base in the third year and an additional one for the head in the seventh year, but the latter is never so large as in the other metacarpal bones. The third metacarpal occasionally has an additional nucleus for the prominent styloid process which may remain distinct and form a *styloid bone*, and traces of a proximal epiphysis have been observed in the second metacarpal bone. In many of the Cetacea (whales, dolphins, and porpoises) and in the seal, epiphyses are found at both ends of the metacarpal bones and phalanges (Flower).

The ossification of a terminal phalanx is peculiar. Like the other phalanges, it has a primary nucleus and a secondary nucleus for an epiphysis. But whereas in other phalanges the primary centre appears in the middle of the shaft, in the case of the distal phalanges the earthy matter is deposited in the free extremity.

Sesamoid Bones

The sesamoid bones are small and rounded and occur imbedded in certain tendons where they exert a considerable amount of pressure on subjacent bony structures. In the hand five sesamoid bones are of almost constant occurrence, namely, two over the metacarpo-phalangeal joint of the thumb in the tendons of the flexor pollicis brevis, one over the interphalangeal joint of the thumb, and one over the metacarpo-phalangeal joints of the second and fifth fingers.

Occasionally sesamoids occur over the metacarpo-phalangeal joint of the third and fourth digits, and an additional one may occur over that of the fifth.

Very rarely a sesamoid is developed in the tendon of the biceps over the tuberosity of the radius.

B. THE BONES OF THE LOWER EXTREMITY

The bones of the lower extremity may be arranged in four groups corresponding to the division of the limb into the *hip, thigh, leg,* and *foot.* In the *hip* is the coxal or hip-bone, which constitutes the pelvic girdle [cingulum extremitatis inferioris], and contributes to the formation of the pelvis; in the *thigh* is the femur; in the *leg,* the tibia and fibula, and in the *foot* the tarsus, metatarsus, and phalanges. Associated with the lower end of the femur is a large sesamoid bone, the patella or knee-cap.

THE COXAL BONE

The **coxal** (innominate) **bone** or hip-bone [os coxæ] (figs. 205, 206) is a large, irregularly shaped bone articulated behind with the sacrum, and in front with its fellow of the opposite side, the two bones forming the anterior and side walls of the pelvis. The coxal bone consists of three parts, named **ilium, ischium,** and **pubis,** which, though separate in early life, are firmly united in the adult. The three parts meet together and form the **acetabulum** (or cotyloid fossa), a large, cup-like socket situated near the middle of the lateral surface of the bone for articulation with the head of the femur.

The **ilium** [os ilium] is the upper expanded portion of the bone, and by its inferior extremity forms the upper two-fifths of the acetabulum. It presents for examination three borders and two surfaces.

Borders.—When viewed from above, the thick **crest** [crista iliaca] or superior border is curved somewhat like the letter *f,* being concave medially in front and concave laterally behind. Its anterior extremity forms the **anterior superior iliac spine,** which gives attachment to the inguinal (Poupart's) ligament and the *sartorius;* the posterior extremity forms the **posterior superior iliac spine** and affords attachment to the sacro-tuberous (great sacro-sciatic) ligament, the posterior sacro-iliac ligament, and the *multifidus.* The crest is narrow in the middle, thick at its extremities, and may be divided into an inner lip, an outer lip, and an intermediate line. About two and a half inches from the anterior superior spine is a prominent tubercle on its external lip.

The external lip of the crest gives attachment in front to the *tensor fasciæ latæ;* along its whole length, to the *fascia lata;* along its anterior half to the *external oblique;* and behind this, for about an inch, to the *latissimus dorsi.* The anterior two-thirds of the intermediate line gives origin to the *internal oblique.* The internal lip gives origin, by its anterior two-thirds, to the *transversus;* behind this is a small area for the *quadratus lumborum,* and the remainder is occupied by the *sacro-spinalis* (*erector spinæ*). The internal lip, in the anterior two-thirds, also serves for the attachment of the iliac fascia.

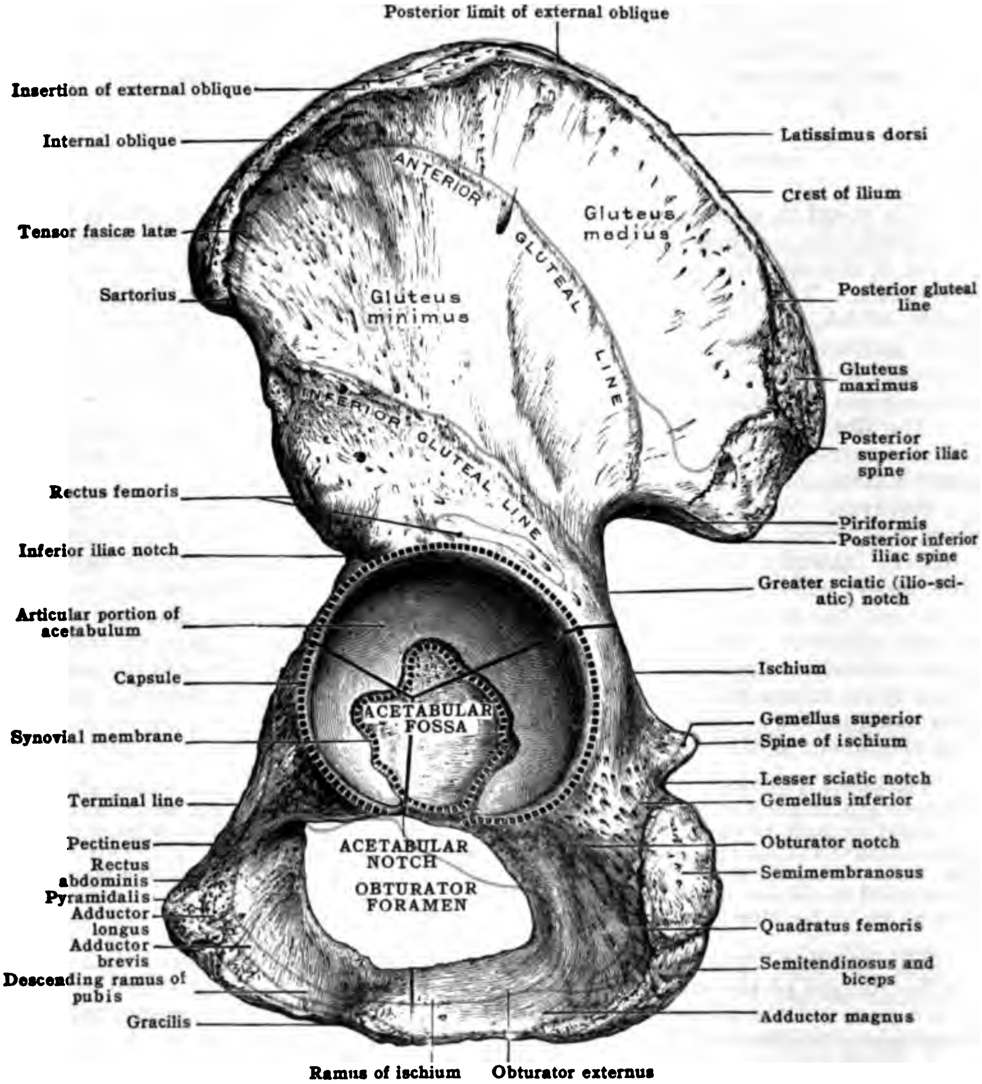
The **anterior border** of the ilium extends from the **anterior superior iliac spine** to the margin of the acetabulum. Below the spine is a prominent notch from which fibres of the *sartorius* arise, and this is succeeded by the **anterior inferior iliac spine,** smaller and less prominent than the superior, to which the straight head of the *rectus* and the ilio-femoral ligament are attached. On the medial side of the anterior inferior spine is a broad, shallow groove for the *ilio-psoas* as it passes from the abdomen into the thigh, limited below by the **ilio-pectineal** eminence, which indicates the point of union of the ilium and pubis.

The **posterior border** of the ilium presents the **posterior superior iliac spine,** and below this, a shallow notch terminating in the **posterior inferior iliac spine** which corresponds to the posterior extremity of the auricular surface and gives attachment to a portion of the sacro-tuberous (great sacro-sciatic) ligament. Below the spine the posterior border of the ilium forms the upper limit of the greater sciatic notch.

Surfaces.—The **external surface** or **dorsum** is concave behind, convex in front, limited above by the thick superior border or **crest,** and traversed by three gluteal lines.

The **posterior gluteal line** commences at the crest about two inches from the posterior superior iliac spine and curves downward to the upper margin of the greater sciatic notch. The space included between this ridge and the crest affords origin at its upper part to the *gluteus maximus*, and at its lower part, to a few fibres of the *piriformis*, while the intermediate portion is smooth and free from muscular attachment. The **anterior gluteal line** begins at the crest, one inch behind its anterior superior iliac spine, and curves across the dorsum to terminate near the lower end of the superior line, at the upper margin of the greater sciatic notch. The surface of bone between this line and the crest is for the origin of the *gluteus medius*. The **inferior gluteal line** commences at the notch immediately below the anterior

FIG. 205.—THE LEFT COXAL OR HIP-BONE. (Lateral view.)



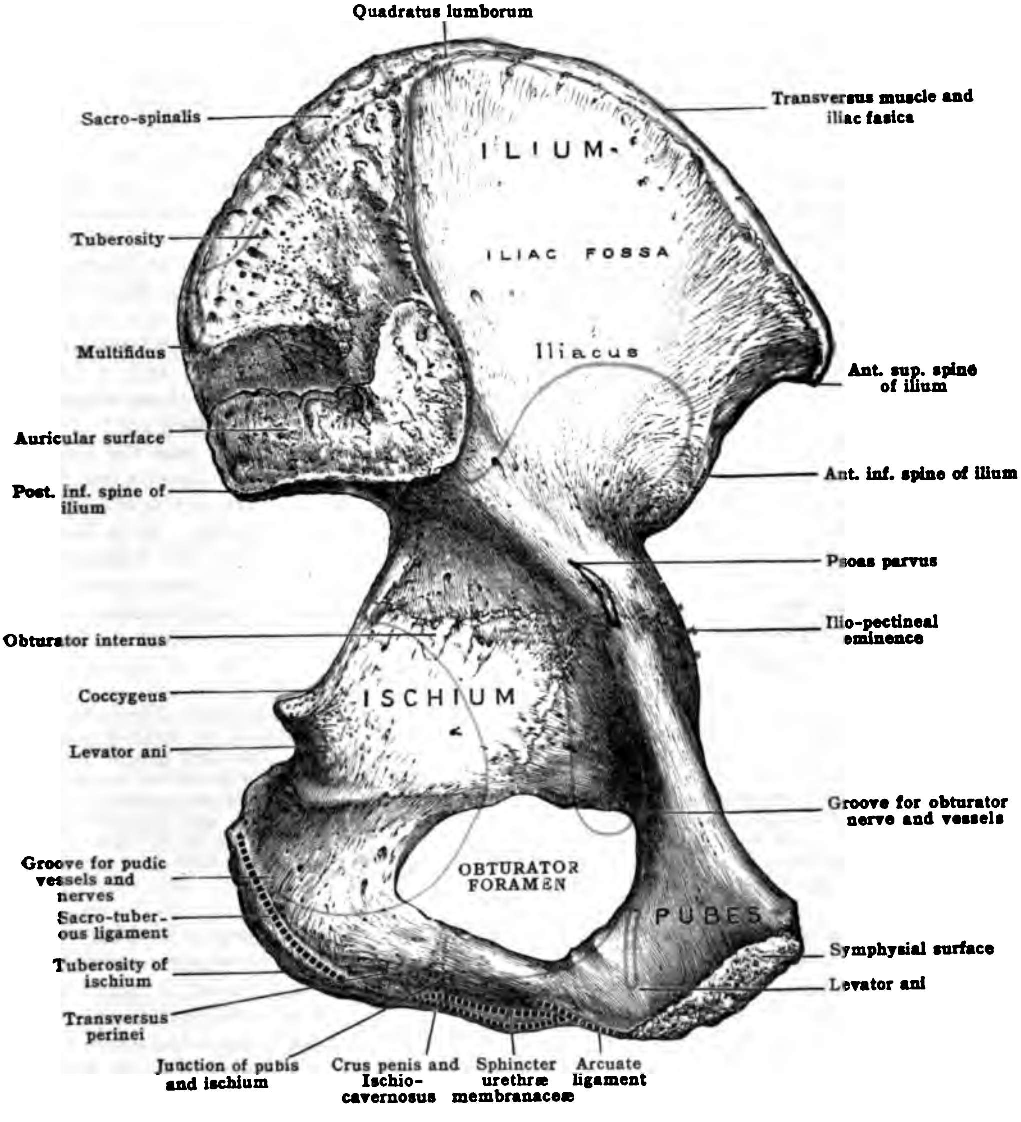
superior iliac spine and terminates posteriorly at the front part of the greater sciatic notch. The space between the anterior and inferior gluteal lines, with the exception of a small area adjacent to the anterior end of the spine for the *tensor fasciæ latæ*, gives origin to the *gluteus minimus*. Between the inferior gluteal line and the margin of the acetabulum the surface affords attachment to the capsule of the hip-joint, and on a rough area (sometimes a depression) toward its anterior part, to the *reflected tendon of the rectus femoris*.

The **internal surface** presents in front a smooth concave portion termed the **iliac fossa**, which lodges the *iliacus* muscle. The fossa is limited below by linea arcuata, the iliac portion of the terminal (ilio-pectineal) line. This is a rounded border separating the fossa from a portion of the internal surface below the line, which gives attachment to the *obturator internus* and enters into the formation of the minor (true) pelvis. Behind the iliac fossa the bone is uneven and presents

an auricular surface, covered with cartilage in the recent state, for articulation with the lateral aspect of the upper portion of the sacrum; above the auricular surface are some depressions for the posterior sacro-iliac ligaments and a rough area reaching as high as the crest, from which parts of the *sacro-spinalis* (*erector spinæ*) and *multifidus* take origin. The rough surface above the auricular facet is known as the **tuberosity of the ilium.**

The **ischium** [os ischii] consists of a body, a tuberosity, and a ramus. The **body,** which has somewhat the form of a triangular pyramid, enters superiorly into

FIG. 206.—THE LEFT COXAL OR HIP-BONE. (Medial aspect.)



the formation of the acetabulum, to which it contributes a little more than two-fifths, and forms the chief part of the non-articular portion or floor. The **inner surface** forms part of the minor (true) pelvis and gives origin to the *obturator internus.* It is continuous with the ilium a little below the terminal (ilio-pectineal) line, and with the pubis in front, the line of junction with the latter being frequently indicated in the adult bone by a rough line extending from the ilio-pectineal eminence to the margin of the obturator foramen. The **outer surface** includes the portion of the acetabulum formed by the ischium. The **posterior surface** is broad and bounded laterally by the margin of the acetabulum and behind

by the posterior border. The capsule of the hip-joint is attached to the lateral part and the *piriformis*, the great sciatic and posterior cutaneous nerves, the inferior gluteal (sciatic) artery, and the nerve to the *quadratus femoris* lie on the surface as they leave the pelvis. Inferiorly this surface is limited by the **obturator groove**, which receives the posterior fleshy border of the *obturator externus* when the thigh is flexed. Of the three borders, the **external,** forming the prominent rim of the acetabulum, separates the posterior from the external surface and gives attachment to the glenoid lip. The **inner border** is sharp and forms the lateral boundary of the obturator foramen. The **posterior border** is continuous with the posterior border of the ilium, with which it joins to complete the margin of the **great sciatic notch** [incisura ischiadica major]. The notch is converted into a foramen by the sacro-spinous (small sacro-sciatic) ligament, and transmits the *piriformis* muscle, the gluteal vessels, the superior and inferior gluteal nerves, the sciatic and posterior cutaneous nerves, the internal pudic vessels and nerve, and the nerves to the *obturator internus* and *quadratus femoris.* Below the notch is the prominent **ischial spine,** which gives attachment internally to the *coccygeus* and *levator ani,* externally to the *gemellus superior,* and at the tip to the sacro-spinous ligament. Below the spine is the **small sciatic notch** [incisura ischiadica minor], covered in the recent state with cartilage, and converted into a foramen by the sacro-tuberous (great sacro-sciatic) ligament. It transmits the tendon of the *obturator internus,* its nerve of supply, and the internal pudic vessels and nerve.

The **rami** form the flattened part of the ischium which runs first downward, then upward, forward and medially from the tuberosity toward the inferior ramus of the pubis, with which it is continuous. The **rami** together form an L-shaped structure with an upper vertical ramus [ramus superior] and a lower horizontal ramus [ramus inferior]. The outer surface of the rami gives origin to the *adductor magnus* and *obturator externus;* the inner surface, forming part of the anterior wall of the pelvis, receives the crus penis (or clitoridis) and the *ischio-cavernosus,* and gives origin to a part of the *obturator internus.* Of the two borders, the upper is thin and sharp, and forms part of the boundary of the obturator foramen; the lower is rough and corresponds to the inferior ramus. It is somewhat everted and gives attachment to the fascia of Colles, and the *transversus perinei.* To a ridge immediately above the impression for the crus penis (or clitoridis) and the *ischio-cavernosus,* the urogenital trigone (triangular ligament) is attached. The posterior and inferior aspect of the superior ramus is an expanded area forming the **tuberosity** [tuber ischiadicum].

The **tuberosity** is that portion of the ischium which supports the body in the sitting posture. It forms a rough, thick eminence continuous with the inferior border of the inferior ramus, and is marked by an oblique line separating two impressions, an upper and lateral for the *semimembranosus,* and a lower and medial for the common tendon of the *biceps* and *semitendinosus,* while the lower part is markedly uneven and gives origin to the *adductor magnus.* The upper border gives origin to the *inferior gemellus;* the inner border, sharp and prominent, receives the sacro-tuberous (great sacro-sciatic) ligament, while the surface of the tuberosity immediately in front is in relation with the internal pudic vessels and nerve. The outer border gives origin to the *quadratus femoris.*

The **pubis** [os pubis] consists of a **body** and two **rami**—superior and inferior. The **body** is somewhat quadrilateral in shape and presents for examination two surfaces and three borders. The **anterior surface** looks downward, forward and slightly outward, and gives origin to the *adductor longus,* the *adductor brevis,* the *obturator externus,* and the *gracilis.* The **posterior surface** is smooth, looks into the pelvis, and affords origin to the *levator ani,* the *obturator internus,* and the pubo-prostatic ligaments. The **upper border** or crest of the body is rough and presents laterally a prominent bony point, known as the **tubercle** [tuberculum pubicum] or spine, for the attachment of the inguinal (Poupart's) ligament. The upper border extends from the pubic tubercle medialward to the upper end of the symphysis, with which it forms the *angle* of the pubis. The upper border is a short horizontal ridge, which gives attachment to the *rectus abdominis* and *pyramidalis.* The **medial border** is oval in shape, rough, and articular, forming with the bone of the opposite side the *symphysis pubis* [facies symphyseos]. The **lateral border** is sharp and forms part of the boundary of the obturator foramen.

The **inferior ramus,** like the inferior ramus of the ischium, with which it is continuous, is thin and flattened. To its **anterior surface** are attached the

adductor brevis, adductor magnus, and *obturator externus.* The **posterior surface** is smooth and gives attachment to the *crus penis* or *clitoridis*, the *sphincter urethræ* (urogenitalis), the *obturator internus*, and the urogenital trigone (triangular ligament). The **lateral border** forms part of the circumference of the obturator foramen, and the **medial border** forms part of the pubic arch and gives attachment to the *gracilis.*

The **superior ramus** extends from the body of the pubis to the ilium, forming by its lateral extremity the anterior one-fifth of the articular surface of the acetabulum. It is prismatic in shape and increases in size as it passes laterally. Above it presents a sharp ridge, the **pecten** or pubic portion of the terminal (ilio-pectineal) line continuous with the iliac portion at the ilio-pectineal eminence, and affording

FIG. 207.—AN IMMATURE COXAL (INNOMINATE) BONE, SHOWING A COTYLOID BONE.

attachment to the conjoined tendon [falx aponeurotica inguinalis], the lacunar (Gimbernat's) ligament, the reflected inguinal ligament (fascia triangularis), and the pubic portion of the fascia lata; the iliac portion of the terminal (ilio-pectineal) line gives attachment to the *psoas minor*, the iliac fascia, and the pelvic fascia. Immediately in front of the pubic portion of the line is the **pectineal surface**; it gives origin at its posterior part to the *pectineus*, and is limited below by the **obturator crest,** which extends from the pubic tubercle to the acetabular notch. The **inferior surface** of the ascending ramus forms the upper boundary of the obturator foramen and presents a deep groove [sulcus obturatorius] for the passage of the obturator vessels and nerve. The **posterior surface** is smooth, forms part of the anterior wall of the pelvic cavity, and gives attachment to a few fibres of the *obturator internus.*

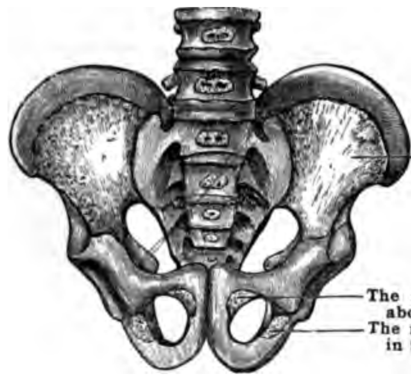
According to the BNA, the body [corpus ossis pubis] is the portion corresponding to the acetabulum. The remainder of the bone is described as consisting of the ramus superior and the ramus inferior, which meet at the symphysis. Thus the divisions according to the BNA are different from those in the description above given.

The **acetabulum** is a circular depression in which the head of the femur is lodged and consists of an articular and a non-articular portion. The articular portion is circumferential and semilunar in shape [facies lunata], with the deficiency in the lower segment. One-fifth of the acetabulum is formed by the pubis, two-fifths by the ischium, and the remaining two-fifths are formed by the ilium. In rare instances the pubis may be excluded by a fourth element, the **cotyloid bone.** The non-articular portion [fossa acetabuli] is formed mainly by the ischium, and is continuous below with the margin of the obturator foramen. The articular portion presents a lateral rim to which the glenoid lip is attached, and a medial margin to which the synovial membrane which excludes

the ligamentum teres from the synovial cavity is connected. The opposite extremities of the articular lunate surface which limit the **acetabular notch** are united by the transverse ligament, and through the **acetabular foramen** thus formed a nerve and vessels enter the joint.

The **obturator** (thyreoid) **foramen** is situated between the ischium and pubis. Its margins are thin, and serve for the attachment of the obturator membrane. At the upper and posterior angle it is deeply grooved for the passage of the obturator vessels and nerve.

FIG. 208.—THE PELVIS OF A FŒTUS AT BIRTH, TO SHOW THE THREE PORTIONS OF THE COXAL BONES.



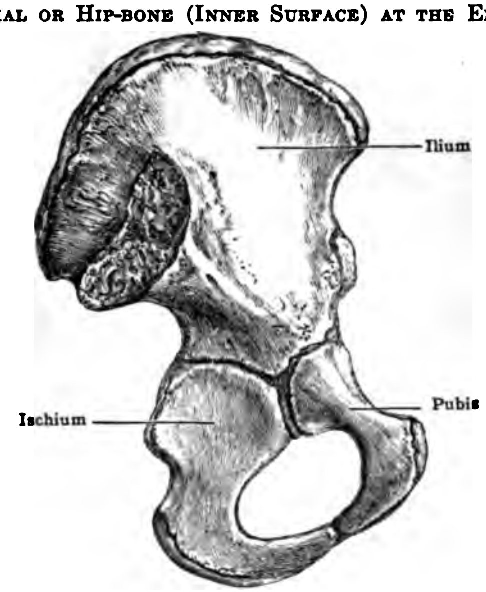
Blood-supply.—The chief vascular foramina of the coxal bone are found where the bone is thickest. On the inner surface, the ilium receives twigs from the ilio-lumbar, deep circumflex iliac, and obturator arteries, by foramina near the crest, in the iliac fossa, and below the terminal line near the greater sciatic notch. On the outer surface the chief foramina are found below the inferior gluteal line and the nutrient vessels are derived from the gluteal arteries. The ischium receives nutrient vessels from the obturator, internal and external circumflex arteries, and the largest foramina are situated between the acetabulum and the ischial tuberosity. The pubis is supplied by twigs from the obturator, internal and external circumflex arteries, and from the pubic branches of the common femoral artery.

FIG. 209.—COXAL OR HIP-BONE, SHOWING SECONDARY CENTRES.

Ossification.—The cartilaginous representative of the hip-bone consists of three distinct portions, an iliac, an ischiatic, and a pubic portion; the iliac and ischiatic portions first unite and later the pubic portion, so that eventually there is found a single cartilaginous mass. Early in the second month a centre of ossification appears above the acetabulum for the ilium. A little later a second nucleus appears below the cavity for the ischium, and this is followed in the fourth month by a deposit in the pubic portion of the cartilage. At birth, the three nuclei

are of considerable size, but are surrounded by relatively wide tracts of cartilage; ossification has, however, extended into the margin of the acetabulum. In the eighth year the rami of the pubis and ischium become united by bone, and in the twelfth year the triradiate cartilage which separates the three segments of the bone in the acetabulum begins to ossify from several centres. Of these, one is more constant than the others and is known as the acetabular nucleus. The triangular piece of bone to which it gives rise is regarded as the representative of the *cotyloid* or acetabular bone, constantly present in a few mammals. It is situated at the medial part of the acetabulum and is of such a size as to exclude entirely the pubis from the cavity. With this bone, however, it eventually fuses, and afterward becomes joined with the ilium and

FIG. 210.—COXAL OR HIP-BONE (INNER SURFACE) AT THE EIGHTH YEAR.



ischium, so that by the eighteenth or twentieth year the several parts of the acetabulum have become united. In the fifteenth year other centres appear in the cartilage of the crest of the ilium, the anterior inferior iliac spine, the tuberosity of the ischium, and the pubic pecten. The epiphyses fuse with the main bone about the twentieth year. The fibrous tissue connected with the tubercle of the pubis represents the epipubic bones of marsupials.

THE PELVIS

The **pelvis** (**figs.** 211, 212, 213, 214) is composed of four bones: the two coxal or hip-bones, the sacrum, and the coccyx. The hip-bones form the lateral and anterior boundaries, meeting each other in front to form the pubic symphysis [symphysis ossium pubis]; posteriorly they are separated by the sacrum. The interior of the pelvis is divided into the **major** and **minor** pelvic cavity.

The **major** (or false) **pelvis** is that part of the cavity which lies above the terminal (iliopectineal) lines and between the iliac fossæ. This part belongs really to the abdomen, and is in relation with the hypogastric and iliac regions.

The **minor** (or true) **pelvis** is situated below the terminal (ilio-pectineal) lines. The upper circumference, known as the **superior aperture** (inlet or brim) of the pelvis, is bounded anteriorly by the tubercle and pecten of the pubis on each side, posteriorly by the anterior margin of the base of the sacrum, and laterally by the terminal lines. The inlet in normal pelves is heart-shaped, being obtusely pointed in front; posteriorly it is encroached upon by the promontory of the sacrum. It has three principal **diameters**; of these, the antero-posterior, called the **conjugate** diameter [conjugata], is measured from the **sacro-vertebral angle** to the symphysis. The **transverse** diameter represents the greatest width of the pelvic cavity. The **oblique** diameter is measured from the sacro-iliac synchondrosis of one side to the ilio-pectineal eminence of the other.

The **cavity** of the minor (true) pelvis is bounded in front by the pubes, behind by the sacrum and coccyx, and laterally by a smooth wall of bone formed in part by the ilium and in part by the ischium. The cavity is shallow in front, where it is formed by the pubes, and is deepest posteriorly.

The **inferior aperture,** or outlet, of the minor pelvis is very irregular, and encroached upon by three bony processes: the posterior process is the coccyx, and the two lateral processes are the ischial tuberosities. They separate three notches. The anterior notch is the **pubic arch,** and is bounded on each side by the conjoined rami of the pubes and ischium. Each of the two remaining gaps, bounded by the

FIG. 211.—THE MALE PELVIS.

ischium anteriorly, the sacrum and coccyx posteriorly, and the ilium above, corresponds to the greater and lesser sciatic notches. These are converted into foramina by the sacro-tuberous (great sacro-sciatic) and sacro-spinous (small sacro-sciatic) ligaments.

The position of the pelvis.—In the erect position of the skeleton the plane of the pelvic inlet forms an angle with the horizontal plane, which varies in individuals from 50° to 60°.

FIG. 212.—THE FEMALE PELVIS.

The base of the sacrum in an average pelvis lies nearly ten centimetres (four inches) above the upper margin of the symphysis pubis.

The axis of the pelvis.—This is an imaginary curved line drawn through the minor pelvis at right angles to the planes of the **inlet, cavity,** and **outlet** through their central points.

As the posterior wall, formed by sacrum and coccyx, is nearly five inches long and concave, and the anterior wall at the symphysis pubis one one and a half to two inches long, it follows that the axis must be curved.

The average measurements of the diameters of the minor pelvis in the three planes are given below:—

	Conjugate or Antero-posterior.	Oblique.	Transverse.
Inlet..............	4¼ inches (10.6 cm.)	5 inches (12.5 cm.)	5¼ inches (13.0 cm.)
Cavity............	4¾ " (11.8 cm.)	5¼ " (13.0 cm.)	4¾ " (11.8 cm.)
Outlet............	3¾ " (9.0 cm.)	4½ " (11.2 cm.)	4¼ " (10.6 cm.)

FIG. 213.—MALE PELVIS. (Lateral view.)

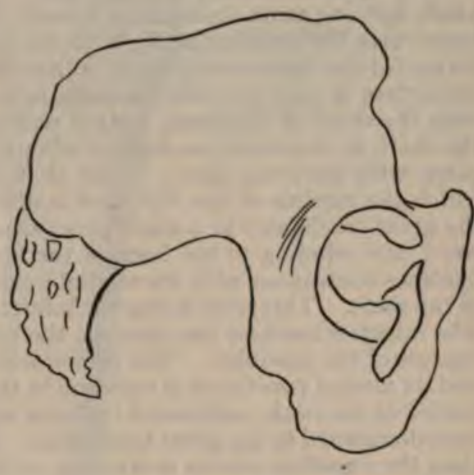


FIG. 214.—FEMALE PELVIS. (Lateral view.)

There is, however, a difference between the sexes, the diameters of the male pelvis in general averaging slightly less, and those of the female slightly greater than the figures above given.

Differences according to sex.—There is a marked difference in the size and form of the male and female pelvis, the pecularities of the latter being necessary to qualify it for its functions in parturition. The various points of divergence may be tabulated as follows:—

Male.	Female.
Bones heavier and rougher.	Bones more slender.
Ilia less vertical.	Ilia more vertical.
Iliac fossæ deeper.	Iliac fossæ shallower.
Major pelvis relatively wider.	Major pelvis relatively narrower.
Minor pelvis deeper.	Minor pelvis shallower.
" " narrower.	" " wider.
Superior aperture more heart-shaped.	Superior aperture more oval.
Symphysis deeper.	Symphysis shallower.
Tuberosities of ischia inflexed.	Tuberosities of ischia everted.
Pubic angle narrow and pointed.	Pubic arch wider and more rounded.
Margins of ischio-pubic rami more everted.	Margins of ischio-pubic rami less everted.
Obturator foramen oval.	Obturator foramen triangular.
Sacrum narrower and more curved.	Sacrum wider and less curved.
Capacity of minor pelvis less.	Capacity of minor pelvis greater.

The sexual characters of the pelvis as shown by A. Thomson are manifest as early as the fourth month of fœtal life.

Quite recently attention has been drawn by D. Derry to some special points in which the os coxæ differ in the two sexes, and two figures are shown here in which one of these points is clearly brought out. It will be seen that the great sciatic notch is larger in the female, and that the sacrum projects less forward at its apex. Moreover the facies auricularis is smaller whilst below and in front of this surface, the *sulcus preauricularis*, a depression for the attachment of the *ligamenta sacroiliaca anteriora*, is usually more pronounced.

In comparison with the pelves of lower animals, which, speaking generally, are elongated and narrow, the human pelvis is characterised by its breadth, shallowness, and great capacity. Differences are also to be recognised in the form of the pelvis in the various races of mankind, the most important being the relation of the antero-posterior to the transverse diameter, measured at the inlet. This is expressed by the *pelvic index* $= \frac{100 \times \text{conjugate diameter}}{\text{transverse diameter}}$.

In the average European male the index is about 80; in the lower races of mankind, 90 to 95. Pelves with an index below 90 are *platypellic*, from 90 to 95 are *mesatipellic*, and above 95 *dolichopellic*. (Sir William Turner.)

THE FEMUR

The **femur** or thigh bone (figs. 215, 216) is the largest and longest bone in the skeleton, and transmits the entire weight of the trunk from the hip to the tibia. In the erect posture it inclines from above downward and medially, approaching at the lower extremity its fellow of the opposite side, but separated from it above by the width of the true pelvis. It presents for examination a superior extremity, including the head, neck, and two trochanters, an inferior extremity, expanded laterally into two condyles, and a shaft.

The **upper extremity** is surmounted by a smooth, globular portion called the **head,** forming more than half a sphere, directed upward and medially for articulation with the acetabulum. With the exception of a small rough depression, the **fovea,** for the ligamentum teres, a little below and behind the centre of the head, its surface is covered with cartilage in the recent state. The head is connected with the shaft by the **neck,** a stout rectangular column of bone which forms with the shaft, in the adult, an angle of about 125°. Its anterior surface is in the same plane with the front aspect of the shaft, but is marked off from it by a ridge to which the capsule of the hip-joint is attached. The ridge, which commences at the great trochanter in a small prominence, or **tubercle,** extends obliquely downward, and winding to the back of the femur, passes by the lesser trochanter and becomes continuous with the medial lip of the linea aspera, on the posterior aspect of the shaft. This ridge forms the **intertrochanteric line** or **spiral line** of the femur. The intertrochanteric line receives the bands of the ilio-femoral thickening of the capsule of the hip-joint. The posterior surface of the neck is smooth and concave and its medial two-thirds is enclosed in the capsule of the hip-joint. The superior border of the neck, perforated by large nutrient foramina, is short and thick, and runs downward to the great trochanter. The inferior border, longer and narrower than the superior, curves downward to terminate at the lesser trochanter.

The **trochanters** are the prominences which afford attachment to the rotator muscles of the thigh; they are two in number—great and lesser.

The **great trochanter** is a thick, quadrilateral process surmounting the junction of the neck with the shaft, and presents for examination two surfaces and four borders. The lateral surface is broad, rough, and continuous with the lateral surface of the shaft. It is marked by a diagonal ridge running from the postero-superior to the antero-inferior angle, which receives the insertion of the *gluteus medius.* The ridge divides the surface into two triangular areas: an upper, covered by the *gluteus medius,* and occasionally separated from it by a bursa, and a lower, covered by a bursa to permit the free gliding of the tendon of the *gluteus maximus.* Of the **medial** surface the lower and anterior portion is joined with the rest of the bone; the upper and posterior portion is free, concave, and presents a deep depression, the **trochanteric** or **digital fossa,** which receives the tendon of the *obturator externus.* The fore part of the surface is marked by an impression for the insertion of the *obturator internus* and two *gemelli.*

Of the four borders, the superior, thick and free, presents near the centre an oval mark for the insertion of the *piriformis;* the anterior border, broad and irregular, receives the *gluteus minimus;* the posterior border, thick and rounded, is continuous with the **intertrochanteric crest,** the prominent ridge uniting the two trochanters behind. Above the middle of this line is an elevation, termed the **tubercle of the quadratus,** for the attachment of the upper part of the *quadratus femoris.* The inferior border corresponds with the line of junction of the base of the trochanter with the shaft; it is marked by a prominent ridge for the origin of the upper part of the *vastus lateralis.*

The **lesser trochanter** is a conical eminence projecting medially from the posterior and medial aspect of the bone, where the neck is continuous with the shaft. Its summit is rough and gives attachment to the tendon of the *ilio-psoas.* The fibres of the *iliacus* extend beyond the trochanter and are inserted into the surface of the shaft immediately below.

The **body** or **shaft** of the femur is almost cylindrical, but is slightly flattened in front and strengthened behind by a projecting longitudinal ridge, the **linea aspera,** for the origin and insertion of muscles. The linea aspera extends along the middle third of the shaft and presents a medial lip and a lateral lip separated by a narrow interval. When followed into the upper third of the shaft, the three parts diverge. The lateral lip becomes continuous with the **gluteal tuberosity** and ends at the base of the great trochanter. The ridge affords insertion to the *gluteus maximus,*

FIG. 215.—THE LEFT FEMUR. (Anterior view.)

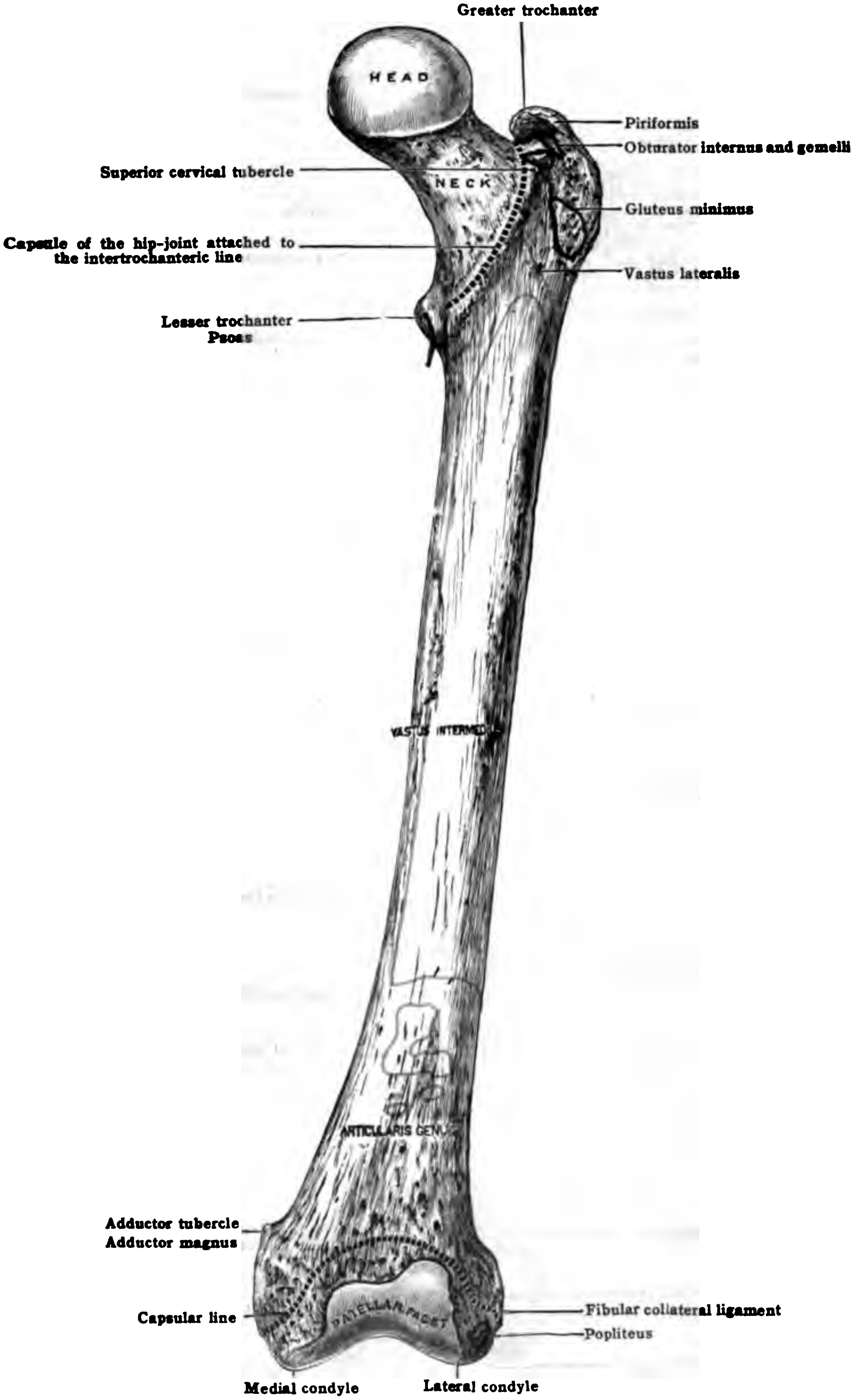
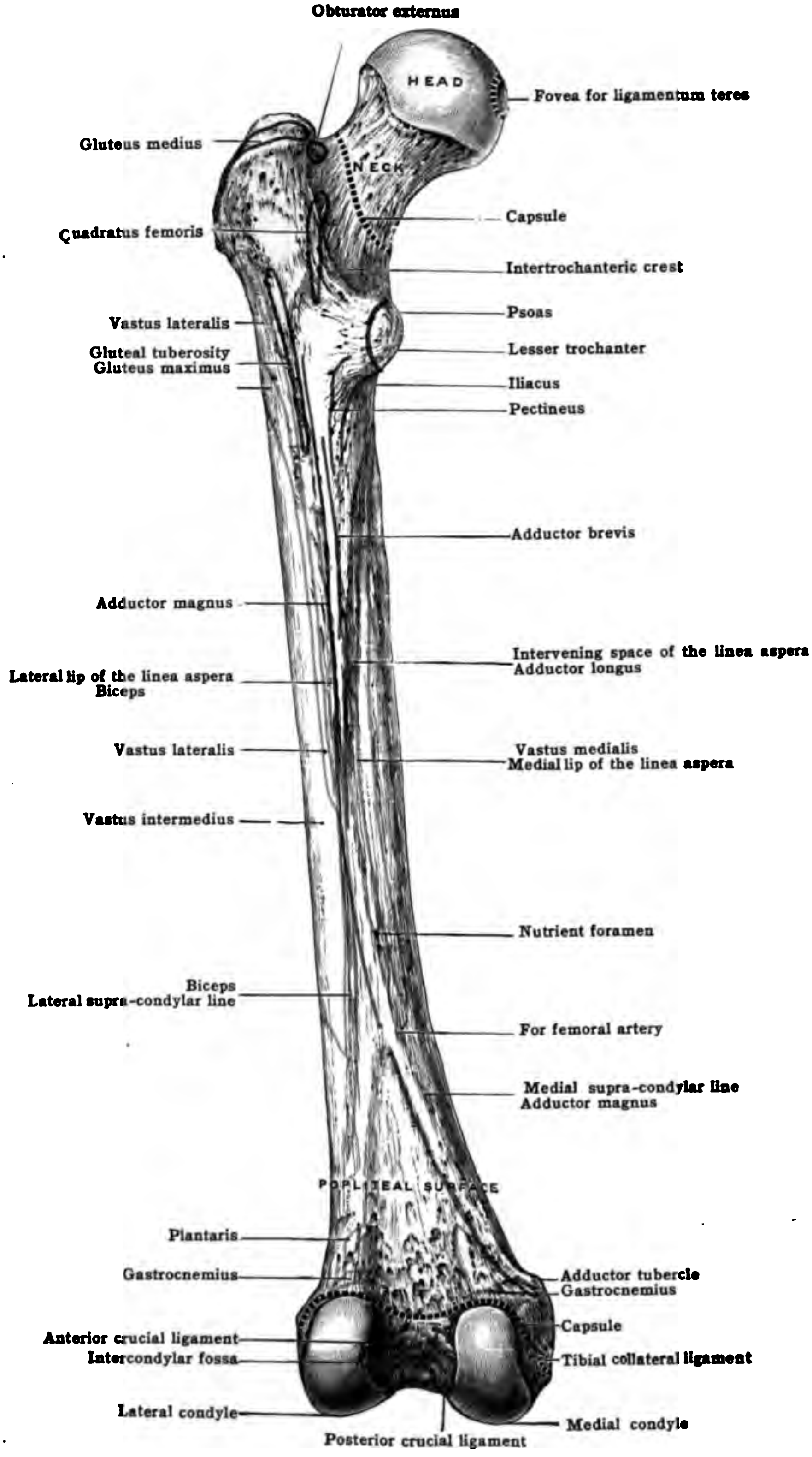


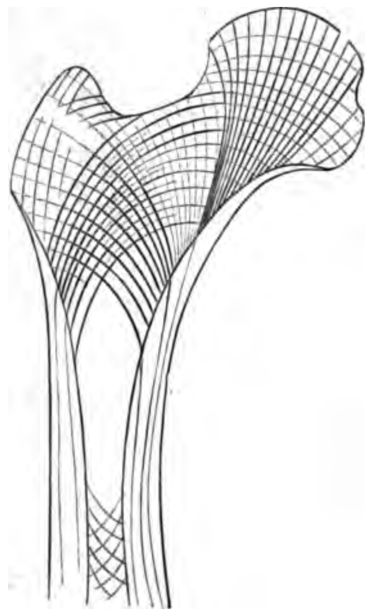
Fig. 216.—The Left Femur. (Posterior view.)



and when very prominent is termed the **third trochanter.** The medial lip curves medialward below the lesser trochanter, where it becomes continuous with the intertrochanteric line; the intervening portion bifurcates and is continued upward as two lines, one of which ends at the small trochanter, and receives some fibres of the *iliacus*, whilst the other is the **linea pectinea** and marks the insertion of the pectineus muscle.

Toward the lower third of the shaft the medial and lateral lips of the linea aspera again diverge, and are prolonged to the condyles by the **medial** and **lateral supra-condylar lines,** enclosing between them a triangular surface of bone, the popliteal surface [**planum popliteum**] of the femur, which forms the upper part of the floor of the popliteal space. The lateral line is the more prominent and terminates below in the lateral epicondyle. The medial one is interrupted above, where the femoral vessels are in relation with the bone, better marked below, where it terminates in the **adductor tubercle,** a small sharp projection at the summit of the medial epicondyle, which affords attachment to the tendon of the *adductor magnus.*

FIG. 217.—A DIAGRAM TO SHOW THE PRESSURE AND TENSION CURVES OF THE FEMUR. (After Wagstaffe.)



Near the centre of the linea aspera is the foramen for the medullary artery, directed upward toward the head of the bone.

From the medial lip of the linea aspera and the lower part of the intertrochanteric line arises the *vastus medialis* (internus), and from the lateral lip and the side of the gluteal ridge arises the *vastus lateralis* (externus). The *adductor magnus* is inserted into the medial lip of the linea aspera, from the medial side of the gluteal tuberosity above, and the medial supra-condylar line below. Between the *adductor magnus* and *vastus medialis* (internus) four muscles are attached: the *pectineus* and *iliacus* above, then the *adductor brevis*, and lowest of all, the *adductor longus*. Above, in the interval between the *adductor magnus* and the *vastus lateralis* (externus), the *gluteus maximus* is inserted; in the interval lower down is the short head of the *biceps*, taking origin from the lower two-thirds of the lateral lip of the linea aspera and the upper two-thirds of the lateral supra-condylar line. On the popliteal surface of the bone, just above the condyles, are two rough areas from which fibres of the two heads of the *gastrocnemius* take origin. Above the area for the lateral head of the gastrocnemius is a slight roughness for the *plantaris*.

For purposes of description it is convenient to regard the shaft of the femur as presenting anterior, medial, and lateral surfaces, although definite borders separating the surfaces from one another do not exist. All three surfaces are smooth and the anterior is not separated from the lateral by ridges of any kind. In the middle third of the shaft the medial and lateral surfaces approach one another behind, being separated by the linea aspera.

The shaft is overlapped on its medial side by the *vastus medialis* (internus), and on its lateral side by the *vastus lateralis* (externus). The upper three-fourths of the anterior and lateral surfaces afford origin to the *vastus intermedius* (crureus), and the lower fourth of the anterior surface, to the *articularis genu* (sub-crureus). The medial surface is free from muscular attachment.

Fig. 218.—Transverse Section of Shaft of Femur to show the Medullary Cavity.

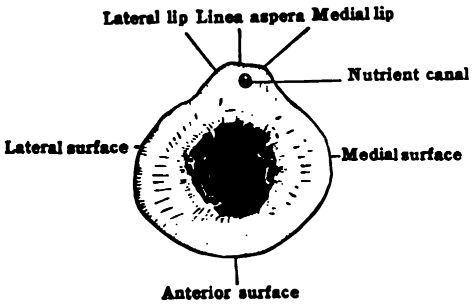
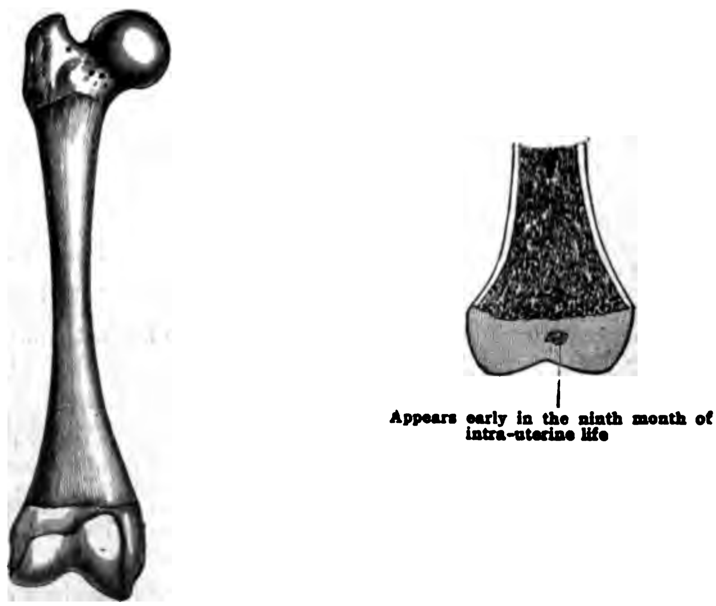


Fig. 219.—Section of Upper End of Femur to show the Calcar Femorale.

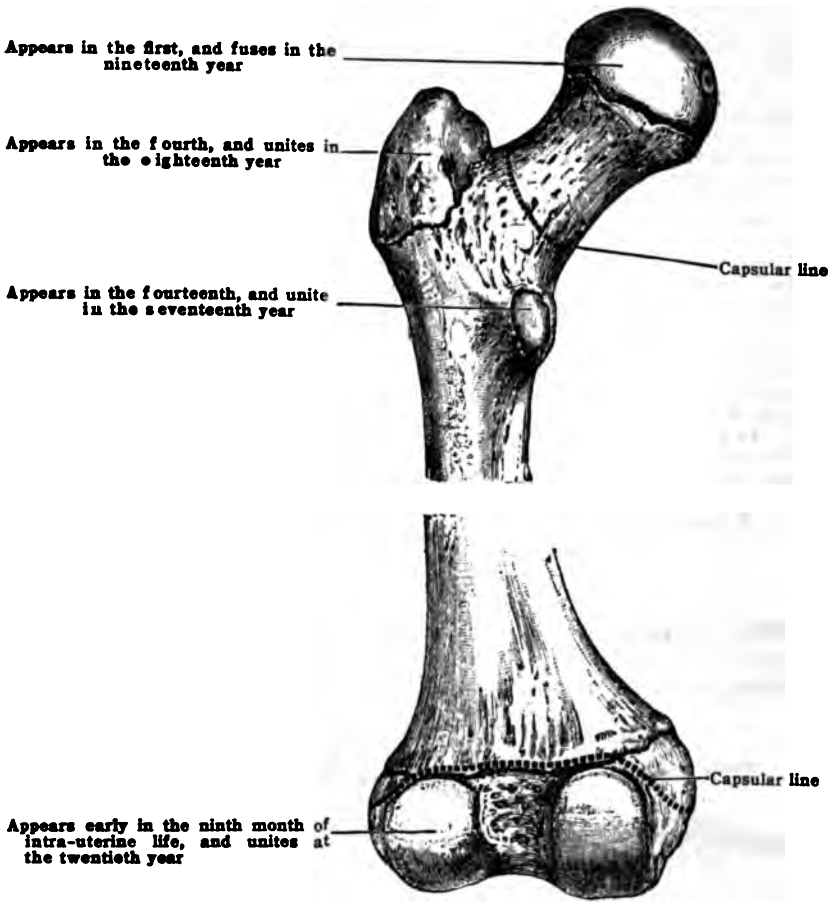
Fig. 220.—The Femur at Birth.



The **lower extremity** presents two cartilage-covered eminences or **condyles**, separated behind by the **intercondyloid fossa.** The lateral condyle is wider than its fellow and more prominent anteriorly; the medial condyle is narrower, more prominent, and longer, to compensate for the obliquity of the shaft. When the femur is in the natural position, the inferior surfaces of the condyles are on the

same plane, and almost parallel, for articulation with the upper surfaces on the head of the tibia. The two condyles are continuous in front, forming a smooth trochlear surface [facies patellaris] for articulation with the patella. This surface presents a median vertical groove and two convexities, the lateral of which is wider, more prominent, and prolonged farther upward. The patellar surface is faintly marked off from the tibial articular surfaces by two irregular grooves, best seen while the lower end is still coated with cartilage. The lateral groove commences on the medial margin of the lateral condyle near the front of the intercondylar fossa, and extends obliquely forward to the lateral margin of the bone. The general direction of the medial groove is from front to back, turning medially in front and extending backward as a faint ridge which marks off from the

FIG. 221.—THE LEFT FEMUR AT THE TWENTIETH YEAR. (Posterior view.)
The figure shows the relations of the epiphysial and capsular lines.



rest of the medial condyle a narrow semilunar facet for articulation with the medial perpendicular facet of the patella in extreme flexion. The grooves receive the semilunar menisci in the extended position of the joint. The tibial surfaces are almost parallel except in front, where the medial turns laterally to become continuous with the patellar surface.

The opposed surfaces of the two condyles form the boundaries of the intercondylar fossa and give attachment to the crucial ligaments which are lodged within it. The posterior crucial ligament is attached to the fore part of the lateral surface of the medial condyle and the anterior crucial ligament to the back part of the medial surface of the lateral condyle. The two remaining surfaces of the condyles are broad and convex, and each presents an **epicondyle** (tuberosity) for the attachment of lateral ligaments. The medial epicondyle, the larger of the two, is surmounted by the adductor tubercle, behind which is an impression for

the medial head of the *gastrocnemius* on the upper aspect of the condyle; below and behind the lateral epicondyle is a deep groove which receives the tendon of the *popliteus* muscle when the knee is flexed, and its anterior end terminates in a pit from which the tendon takes origin. Above the lateral epicondyle is a rough impression for the lateral head of the *gastrocnemius*.

The interior of the shaft of the femur is hollowed out by a large medullary canal, and the extremities are composed of cancellated tissue invested by a thin compact layer. The arrangement of the cancelli in the upper end of the bone forms a good illustration of the effect produced by the mechanical conditions to which bones are subject. In the upper end of the bone the cancellous tissue is arranged in divergent curves. One system springs from the lower part of the neck and upper end of the shaft medially and spreads into the great trochanter ('pressure lamellæ'). A second system springs from the lateral part of the shaft and arches upward into the neck and head ('tension lamellæ'), crossing the former almost at right angles. A second set of pressure lamellæ springs from the lower thick wall of the neck, and extends into the upper part of the head to end perpendicularly in the articular surface mainly along the lines of greatest pressure. A nearly vertical plate of compact tissue (**calcar femorale**) projects into the neck of the bone from the inferior cervical tubercle toward the great trochanter. This is placed in the line through which the weight of the body falls, and adds to the stability of the neck of the bone; it is said to be liable to absorption in old age. In the lower end of the bone the vertical and horizontal fibres are so disposed as to form a rectangular meshwork.

Blood-supply.—The head and neck of the femur receive branches from the inferior gluteal, obturator, and circumflex arteries, and the trochanters from the circumflex arteries. The nutrient vessel of the shaft is derived from either the second or third perforating artery, or there may be two nutrient vessels arising usually from the first and third perforating. The vessels of the inferior extremity arise from the articular branches of the popliteal and the anastomotic branch of the femoral (supremagenu).

Ossification.—The femur is ossified from one primary centre for the shaft and from four epiphysial centres. The shaft begins to ossify in the seventh week of intra-uterine life. Early in the ninth month a nucleus appears for the lower extremity. During the first year the nucleus for the head of the bone is visible, and in the fourth year that for the trochanter major. The centre for the lesser trochanter appears about the thirteenth or fourteenth year. The lesser trochanter joins the shaft at the seventeenth, the great trochanter at the eighteenth, the head about the nineteenth, and the lower extremity at the twentieth year.

The neck of the femur is an *apophysis*, or outgrowth from the shaft. The line of fusion of the condylar epiphysis with the shaft passes through the adductor tubercle.

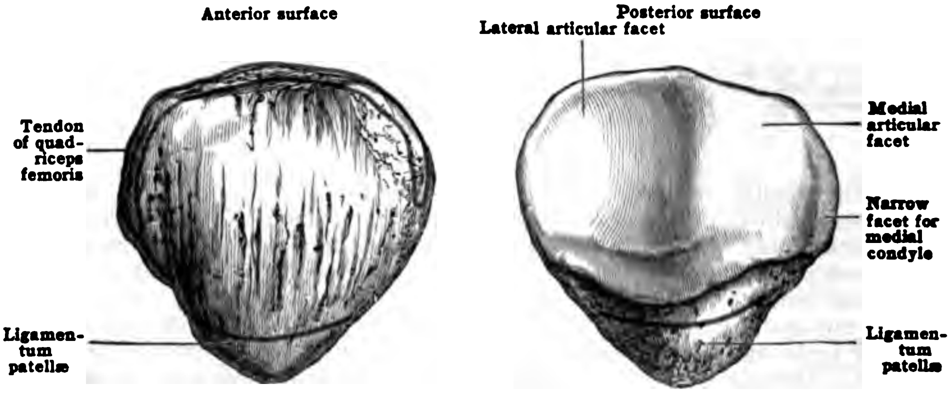
The morphological relation of the patellar facet to the tibial portions of the condyles is worthy of notice. In a few mammals, such as the ox, this facet remains separated from the condyles by a furrow of rough bone.

The angle which the neck of the femur forms with the shaft at birth measures, on an average, 160°. In the adult it varies from 110° to 140°; hence the angle decreases greatly during the period of growth. When once growth is completed, the angle, as a rule, remains fixed. (Humphry.)

THE PATELLA

The **patella** (fig. 222) or knee-pan, situated in front of the knee-joint, is a sesamoid bone, triangular in shape, developed in the tendon of the *quadriceps femoris*. Its **anterior surface**, marked by numerous longitudinal striæ, is slightly convex, and

Fig. 222.—The Left Patella.

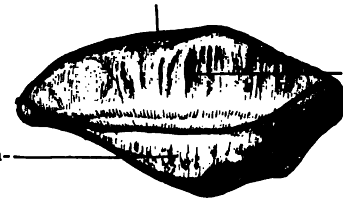


perforated by small openings which transmit nutrient vessels to the interior of the bone. It is covered in the recent state by a few fibres prolonged from the common tendon of insertion (supra-patellar tendon) of the *quadriceps femoris*, into the ligamentum patellæ (infra-patellar tendon), and is separated from the skin by one

or more bursæ. The **posterior surface** is largely articular, covered with cartilage in the recent state, and divided by a slightly marked vertical ridge, corresponding to the groove on the trochlear surface of the femur, into a lateral larger portion for the lateral condyle, and a medial smaller portion for the medial condyle. Close to the medial edge a faint vertical ridge sometimes marks off a narrow articular facet, for the lateral margin of the medial condyle of the femur in extreme flexion of the leg. Below the articular surface is a rough, non-articular depression, giving attachment to the ligamentum patellæ, and separated by a mass of fat from the head of the tibia.

The **base** or superior border is broad, sloped from behind downward and forward, and affords attachment, except near the posterior margin, to the common

FIG. 223.—THE SUPERIOR BORDER OR BASE OF THE LEFT PATELLA.



tendon of the *quadriceps*. The **borders,** thinner than the base, converge to the apex below, and receive parts of the two *vasti* muscles. The **apex** forms a blunt point directed downward, and gives attachment to the ligamentum patellæ, by which the patella is attached to the tibia.

Structurally the patella consists of dense cancellous tissue covered by a thin compact layer, and it receives nutrient vessels from the articular branch of the suprema genu (anastomotic), the anterior tibial recurrent, and the inferior articular branches of the popliteal.

Ossification.—The cartilaginous deposit in the tendon of the *quadriceps* muscle takes place in the fourth month of intra-uterine life. Ossification begins from a single centre during the third year, and is completed about the age of puberty.

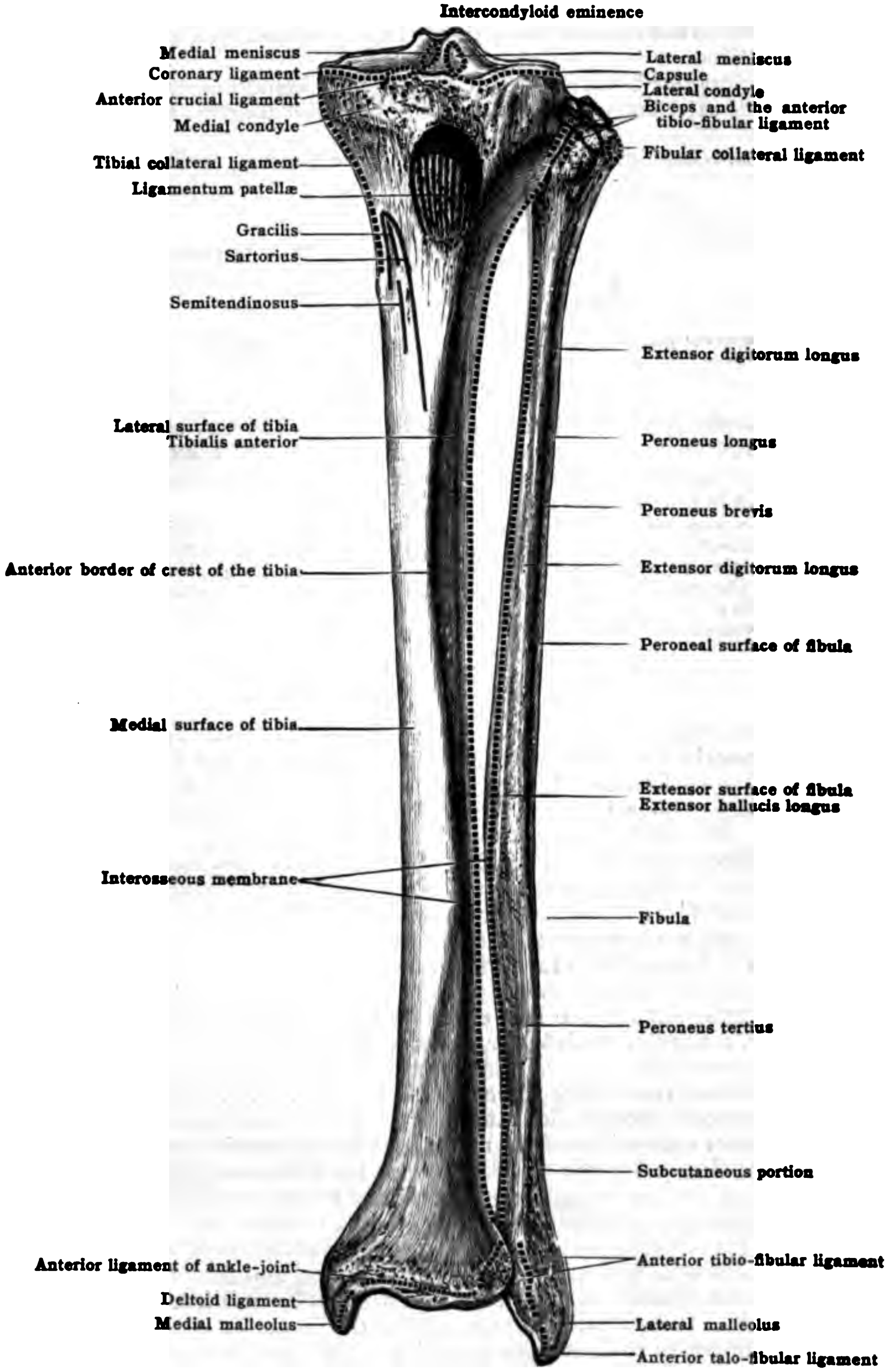
THE TIBIA

The **tibia** (figs. 224, 225) or shin-bone is situated at the front and medial side of the leg and nearly parallel with the fibula. Excepting the femur, it is the largest bone in the skeleton, and alone transmits the weight of the trunk to the foot. It articulates above with the femur, below with the tarsus, and laterally with the fibula. It is divisible into two extremities and a shaft.

The **upper extremity** (or head) consists of two lateral eminences, or **condyles.** Their superior articular surfaces receive the condyles of the femur, the articular parts being separated by a non-articular interval, to which ligaments are attached. The medial articular surface is oval in shape and concave for the medial condyle of the femur. The lateral articular surface is smaller, somewhat circular in shape, and presents an almost plane surface for the lateral condyle. The peripheral portion of each articular surface is overlaid by a fibro-cartilaginous meniscus of semilunar shape, connected with the margins of the condyles by bands of fibrous tissue termed coronary ligaments. Each semilunar meniscus is attached firmly to the rough interval separating the articular surfaces. This interval is broad and depressed in front, **the anterior intercondyloid fossa,** where it affords attachment to the anterior extremities of the medial and lateral menisci and the anterior crucial ligament; elevated in the middle to form the **intercondyloid eminence** or spine of the tibia, a prominent eminence, presenting at its summit two compressed **intercondyloid tubercles,** on to which the condylar articular surfaces are prolonged; the posterior aspect of the base of the eminence affords attachment to the posterior extremities of the lateral and medial semilunar menisci, and limits a deep notch, inclined toward the medial condyle, known as the **posterior intercondyloid fossa** or popliteal notch. It separates the condyles on the posterior aspect of the head and gives attachment to the posterior crucial ligament, and part of the posterior ligament of the knee-joint. Anteriorly, the two condyles are confluent, and form a somewhat flattened surface of triangular outline, the apex of which forms the **tuberosity** of the tibia. The tuberosity is divisible into two parts. The upper

part, rounded and smooth, receives the attachment of the ligamentum patellæ. The lower part is rough, and into its lateral edges prolongations of the ligamentum patellæ are inserted. A prominent bursa intervenes between the ligament and the anterior aspect of the upper extremity of the bone.

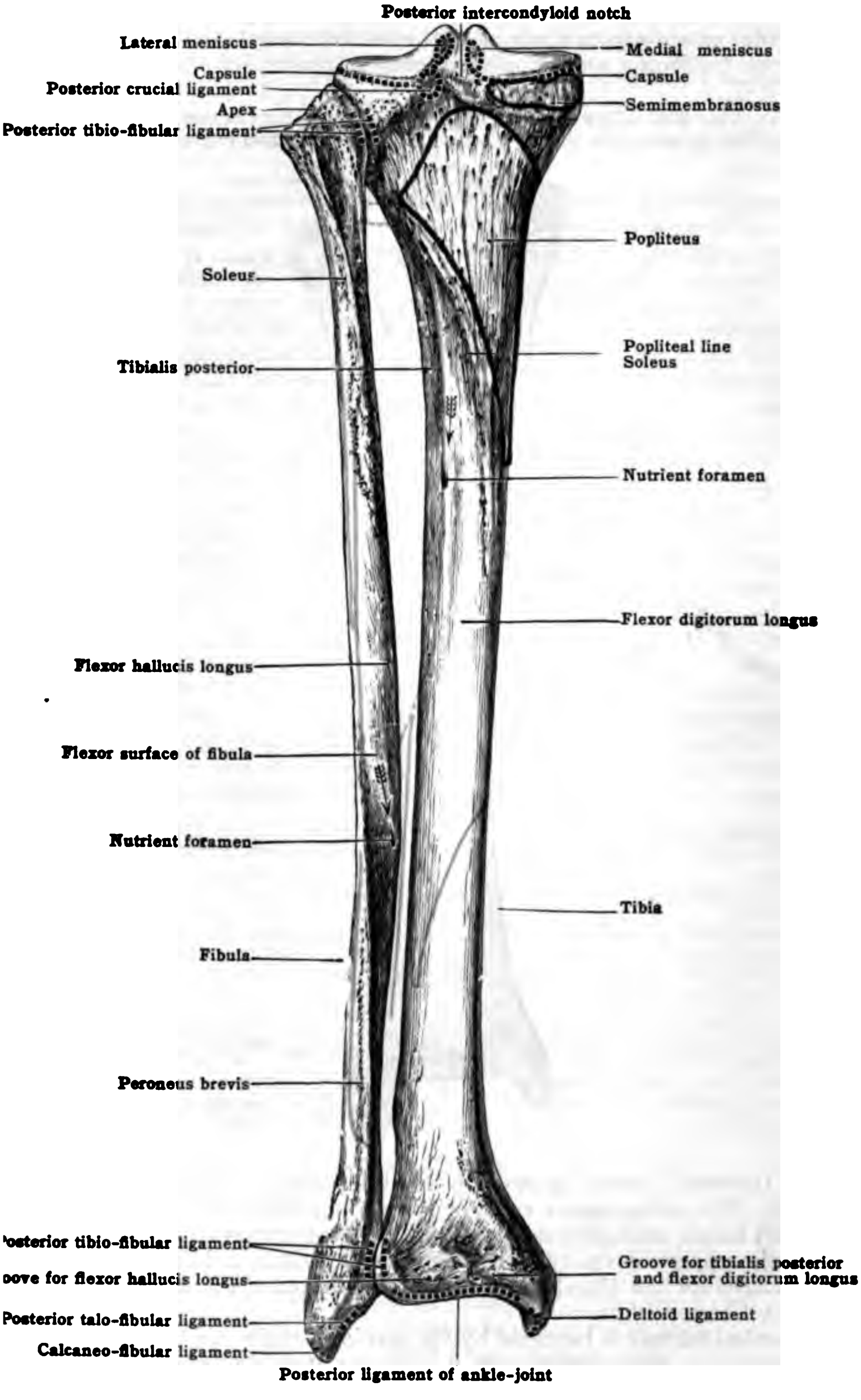
FIG. 224.—THE LEFT TIBIA AND FIBULA. (Anterior view.)



The medial condyle is less prominent though more extensive than the lateral, and near the posterior part of its circumference is a deep horizontal groove for the attachment of the central portion of the *semimembranosus* tendon. The margins of this groove, and the surface

›one below, give attachment to the tibial (internal) lateral ligament of the knee. On the er aspect of the lateral condyle is a rounded articular facet for the head of the fibula, flat nearly circular in outline, directed downward, backward, and laterally. The circumfer- › of the facet is rough and gives attachment to the ligaments of the superior tibio-fibular t, while above and in front of the facet, at the junction of the anterior and lateral surfaces

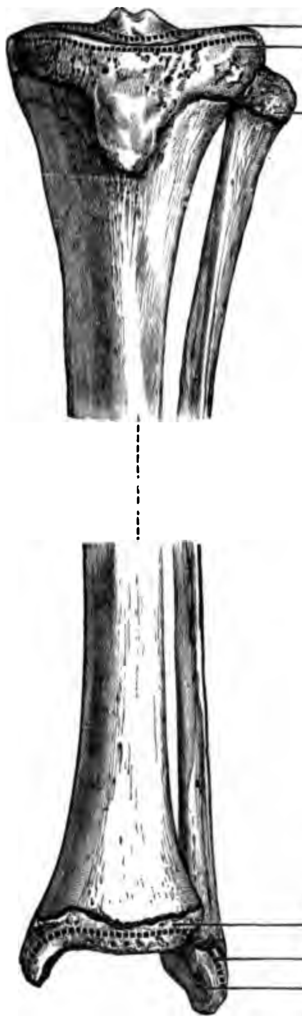
FIG. 225.—THE LEFT TIBIA AND FIBULA. (Posterior view.)



›e condyle, is a ridge for the ilio-tibial band. A slip from the tendon of the *biceps* and parts he *extensor longus digitorum* and *peroneus longus* muscles are attached to the head below ilio-tibial band.

The **shaft** or body [corpus] of the tibia, thick and prismatic above, becomes thinner as it descends for about two-thirds of its length, and then gradually expands toward its lower extremity. It presents for examination three borders and three surfaces. The **anterior border** is very prominent and known as the **anterior crest** of the tibia. It commences above on the lateral edge of the tuberosity and terminates below at the anterior margin of the medial malleolus. It runs a somewhat sinuous course, and gives attachment to the deep fascia of the leg. The **medial border** extends from the back of the medial condyle to the posterior margin of the medial malleolus, and affords attachment above, for about three inches, to

Fig. 226.—The Tibia and Fibula at the Sixteenth Year.
The figure shows the relations of the epiphysial and capsular lines.



the tibial (internal) lateral ligament of the knee-joint and in the middle third, to the *soleus*. The **interosseous crest** or lateral border, thin and prominent, gives attachment to the interosseous membrane. It commences in front of the fibular facet, on the upper extremity, and toward its termination bifurcates to enclose a triangular area for the attachment of the interosseous ligament uniting the lower ends of the tibia and fibula.

The **medial surface** is bounded by the medial margin and the anterior crest; it is broad above, where it receives the insertions of the *sartorius*, *gracilis*, and *semitendinosus;* convex and subcutaneous in the remainder of its extent. The **lateral surface** lies between the crest of the tibia and the interosseous crest. The upper two-thirds presents a hollow for the origin of the *tibialis anterior;* the rest of the

surface is convex and covered by the extensor tendons and the anterior tibial vessels. The **posterior surface** is limited by the interosseous crest and the medial border. The upper part is crossed obliquely by a rough **popliteal line,** extending from the fibular facet on the lateral condyle to the medial border, a little above the middle of the bone.

The popliteal line gives origin to the *soleus* and attachment to the popliteal fascia, while the triangular surface above is occupied by the *popliteus* muscle. Descending along the posterior surface from near the middle of the popliteal line is a vertical ridge, well marked at its commencement, but gradually becoming indistinct below. The portion of the surface between the ridge and the medial border gives origin to the *flexor digitorum longus;* the lateral and narrower part, between the ridge and the interosseous border, to fibres of the *tibialis posterior*. The lower third of the posterior surface is covered by flexor tendons and the posterior tibial vessels. Immediately below the popliteal line and near the interosseous border is the large medullary foramen directed obliquely downward.

The **lower extremity,** much smaller than the upper, is quadrilateral in shape and presents a strong process called the **medial malleolus,** projecting downward from its medial side. The anterior surface of the lower extremity is smooth and rounded above, where it is covered by the extensor tendons, rough and depressed below for the attachment of the anterior ligament of the ankle-joint. It sometimes bears a facet for articulation with the neck of the talus (astragalus). (A. Thomson.) The posterior surface is rough and is marked by two grooves. The medial and deeper of the two encroaches on the malleolus, and receives the tendons of the *tibialis posterior* and *flexor digitorum longus;* the lateral, very shallow and sometimes indistinct, is for the tendon of the *flexor hallucis longus*. The lateral surface is triangular and hollowed for the reception of the lower end of the fibula and rough for the interosseous ligament which unites the two bones, except near the lower border, where there is usually a narrow surface, elongated from before backward, covered with cartilage in the recent state for articulation with the fibula. The lines in front of and behind the triangular surface afford attachment to the anterior and posterior ligaments of the inferior tibio-fibular articulation. The medial surface, prolonged downward on the medial malleolus, is rough, convex, and subcutaneous. The lateral surface of this process is smooth and articulates with the facet on the medial side of the talus (astragalus). Its lower border is notched, and from the notch, as well as from the tip and anterior border, the fibres of the deltoid ligament of the ankle-joint descend. The inferior or terminal surface, by which the tibia articulates with the talus, is of quadrilateral form, concave from before backward, wider in front than behind, and laterally than medially where it is continuous with the lateral surface of the malleolus.

The occasional facet on the anterior surface of the lower extremity of the tibia is a pressure facet, produced by extreme flexion of the ankle joint. It is therefore sometimes designated as the "squatting facet." (See fig. 333.)

Blood-supply.—The tibia is a very vascular bone. The nutrient artery of the shaft is furnished by the posterior tibial, and is the largest of its kind in the body. The head of the bone receives numerous branches from the inferior articular arteries of the popliteal and the recurrent branches of the anterior and posterior tibial. The lower extremity receives twigs from the posterior and anterior tibial, the peroneal, and the medial malleolar arteries.

Ossification.—The tibia is ossified from one principal centre for the shaft, which appears in the eighth week of intra-uterine life, and two epiphyses, the centres for which appear in the cartilaginous head of the bone toward the end of the ninth month, and in the lower extremity during the second year. The latter unites with the shaft at eighteen, but the union of the head with the shaft does not take place until the twenty-first year, and it may even be delayed until twenty-five. The upper part of the tubercle of the tibia is ossified from the upper epiphysis, and the lower part from the diaphysis.

THE FIBULA

The **fibula** (figs. 224, 225) is situated on the lateral side of the leg and, in proportion to its length is the most slender of all the long bones. It is placed nearly parallel to the tibia with which it is connected above and below. In man it is a rudimentary bone and bears none of the weight of the trunk, but is retained on account of the muscles to which it gives origin and its participation in the formation of the ankle-joint. Like other long bones, it is divisible into a shaft and two extremities.

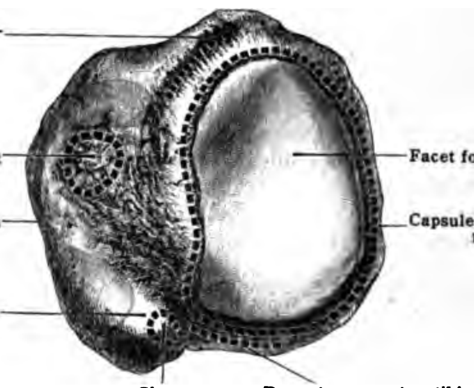
The **head** [capitulum fibulæ], or upper extremity, is a rounded prominence. Its upper surface presents laterally a rough eminence for the attachment of the

biceps tendon and the fibular (long external) collateral ligament of the knee-joint, medially it presents a round or oval facet [facies articularis capituli], directed upward, forward, and medially, for articulation with the lateral condyle (tuberosity) of the tibia. The margin of the facet gives attachment to the articular capsule of the superior tibio-fibular articulation. Posteriorly, the head rises into a pointed **apex** (styloid process), which affords attachment to the short lateral ligament of the knee-joint, and on the lateral side, to part of the *biceps* tendon.

The posterior aspect of the head gives attachment to the *soleus*, the lateral aspect, extending also in front of the eminence for the *biceps*, to the *peroneus longus;* from the anterior aspect fibres of the *extensor digitorum longus* arise, whilst the medial side lies adjacent to the tibia.

The **shaft** [corpus fibulæ], in its upper three-fourths, is quadrangular, possessing four borders and four surfaces, whereas its lower fourth is flattened from side to side, so as to be somewhat triangular. The borders and surfaces vary exceedingly so that their description is difficult. The **anterior crest** (or antero-lateral border) commences in front of the head and terminates below by dividing to enclose a subcutaneous surface, triangular in shape, immediately above the

FIG. 227.—THE UPPER END OF THE LEFT FIBULA TO SHOW MUSCULAR AND LIGAMENTOUS ATTACHMENTS × 2. (G. J. Jenkins.)



lateral malleolus. It gives attachment to a septum separating the extensor muscles in front from the peronei muscles on the lateral aspect. The **interosseous crest** (or antero-medial border), so named from giving attachment to the interosseous membrane, also commences in front of the head, close to the anterior crest, and terminates below by dividing to enclose a rough triangular area immediately above the facet for the *talus* (*astragalus*); this area gives attachment to the inferior interosseous ligament, and may present at its lower end a narrow facet for articulation with the tibia. The **medial crest** (or postero-medial border), sometimes described as the **oblique line** of the fibula, commences at the medial side of the head and terminates below by joining the interosseous crest, in the lower fourth of the shaft. It gives attachment to an aponeurosis separating the *tibialis posterior* from the *soleus* and *flexor hallucis longus*. The **lateral crest** (or postero-lateral border) runs from the back of the head to the medial border of the peroneal groove on the back of the lower extremity; it gives attachment to the fascia separating the peronei from the flexor muscles.

The **anterior** or **extensor surface** is the interval between the interosseous and anterior crests. In the upper third it is extremely narrow, but broadens out below, where it is slightly grooved longitudinally. It affords origin to three muscles: laterally, in the upper two-thirds, to the *extensor digitorum longus*, and, in the lower third, to the *peroneus tertius;* medially, in the middle third, also to the *extensor hallucis longus*. The **medial surface,** situated between the interosseous and medial crests, is narrow above and below, and broadest in the middle. It is grooved and sometimes crossed obliquely by a prominent ridge, the **secondary oblique line** of the fibula; the surface gives origin to the *tibialis posterior*, and the ridge to a tendinous septum in the substance of the muscle. The **posterior surface**

is the interval between the medial and lateral crests, and is somewhat twisted so as to look backward above and medially below. It serves, in its upper third, for the origin of the *soleus*, and in its lower two-thirds for the *flexor hallucis longus*. Near the middle of the surface is the medullary foramen, directed downward toward the ankle. The **lateral surface,** situated between the anterior and lateral crests, is also somewhat twisted, looking laterally above and backward below, where it is continuous with the groove on the back of the lateral malleolus. The surface is often deeply grooved and is occupied by the *peroneus longus* in the upper two-thirds and by the *peroneus brevis* in the lower two-thirds.

The **lateral malleolus** or lower extremity is pyramidal in form, somewhat flattened from side to side, and joined by its base to the shaft. It is longer, more prominent, and descends lower than the medial malleolus. Its lateral surface is convex, subcutaneous, and continuous with the triangular subcutaneous surface on the shaft, immediately above. The medial surface is divided into an anterior and upper area [facies articularis malleoli], triangular in outline and convex from above downward for articulation with the lateral side of the talus (astragalus), and a lower and posterior excavated area, the **digital fossa,** in which are attached the transverse inferior tibio-fibular ligament and the posterior talo-fibular (posterior fasciculus of the external lateral) ligament of the ankle. The anterior border is rough and gives attachment to the anterior talo-fibular (anterior fasciculus of the external lateral) ligament of the ankle, and the anterior inferior tibio-fibular ligament. The posterior border is grooved for the peronei tendons, and near its upper part gives attachment to the posterior inferior tibio-fibular ligament. The apex or summit of the process affords attachment to the calcaneo-fibular (middle fasciculus of the external lateral) ligament of the ankle.

Blood-supply.—The shaft of the fibula receives its nutrient artery from the peroneal branch of the posterior tibial. The head is nourished by branches from the inferior lateral articular branch of the popliteal artery, and the lateral malleolus is supplied mainly by the peroneal, and its perforating and malleolar branches.

Ossification.—The shaft of the fibula commences to ossify in the eighth week of intra-uterine life. A nucleus appears for the lower extremity in the second year, and one in the upper extremity during the fourth or fifth year. The lower extremity fuses with the shaft about twenty, but the upper extremity remains separate until the twenty-second year or even later.

It is interesting, in connection with the times of appearance of the two epiphyses of the fibula, to note that the ossification of the lower epiphysis is contrary to the general rule—viz., that the epiphysis toward which the nutrient artery is directed is the last to undergo ossification. This is perhaps explained by the rudimentary nature of the upper extremity. In birds the head of the bone is large and enters into the formation of the knee-joint; and in human embryos, during the second month, the fibula is quite close up to the femur.

The human fibula is characterised by the length of its malleolus, for in no other vertebrate does this process descend so far below the level of the tibial malleolus. On the other hand, in the majority of mammals the tibial descends to a lower level than the fibular malleolus. In the human embryo of the third month, the lateral is equal in length to the medial malleolus. At the fifth month the lateral malleolus exceeds the medial by 1.5 mm.; at birth, the lateral malleolus is still longer; and by the second year it assumes its adult proportion.

THE TARSUS

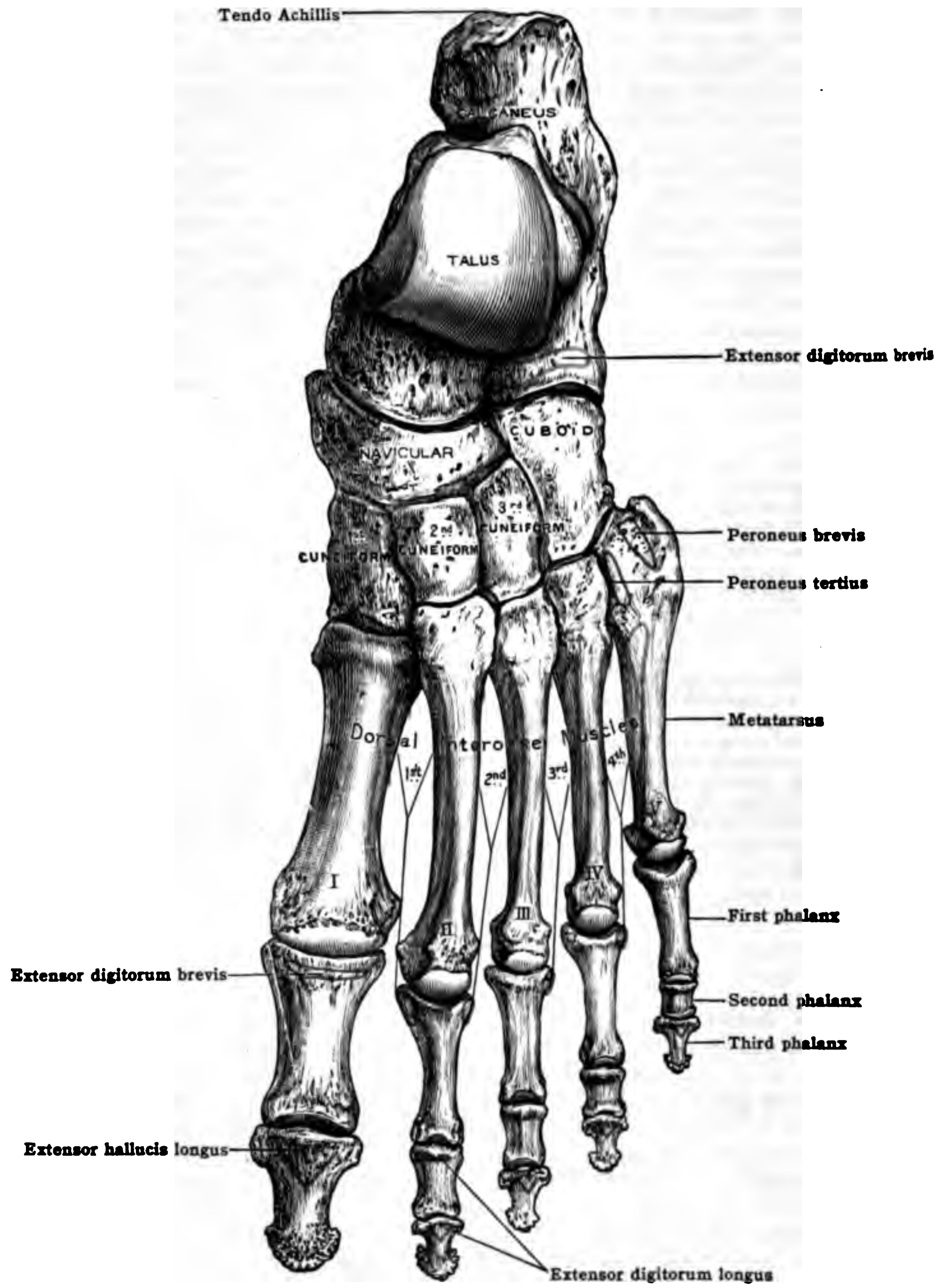
The **tarsal bones** [ossa tarsi] (figs. 228, 229) are grouped in two rows:—a proximal row, consisting of the **talus** and **calcaneus,** and a distal row, consisting of four bones which, enumerated from tibial side, are the **first, second,** and **third cuneiform** bones and the **cuboid.** Interposed between the two rows on the tibial side of the foot is a single bone, the **navicular;** on the fibular side the proximal and distal rows come into contact.

Compared with the carpus, the tarsal bones present fewer common characters, and greater diversity of size and form, in consequence of the modifications for supporting the weight of the trunk. On each, however, six surfaces can generally be recognised, articular when in contact with neighbouring bones, elsewhere subcutaneous or rough for the attachment of ligaments. As regards ossification, they correspond in the main with that of the bones of the carpus. Each tarsal bone is ossified from a single centre, but the calcaneus has, in addition, an epiphysis for a large part of its posterior extremity, and the talus, an occasional centre for the os trigonum.

THE TALUS

The **talus** (or astragalus) (figs. 230, 231) is, next to the calcaneus, the largest of the bones of the tarsus. Above it supports the tibia, below it rests on the calcaneus, at the sides it articulates with the two malleoli, and in front it is received into the navicular. For descriptive purposes, it may be divided into a **head, neck,** and **body.**

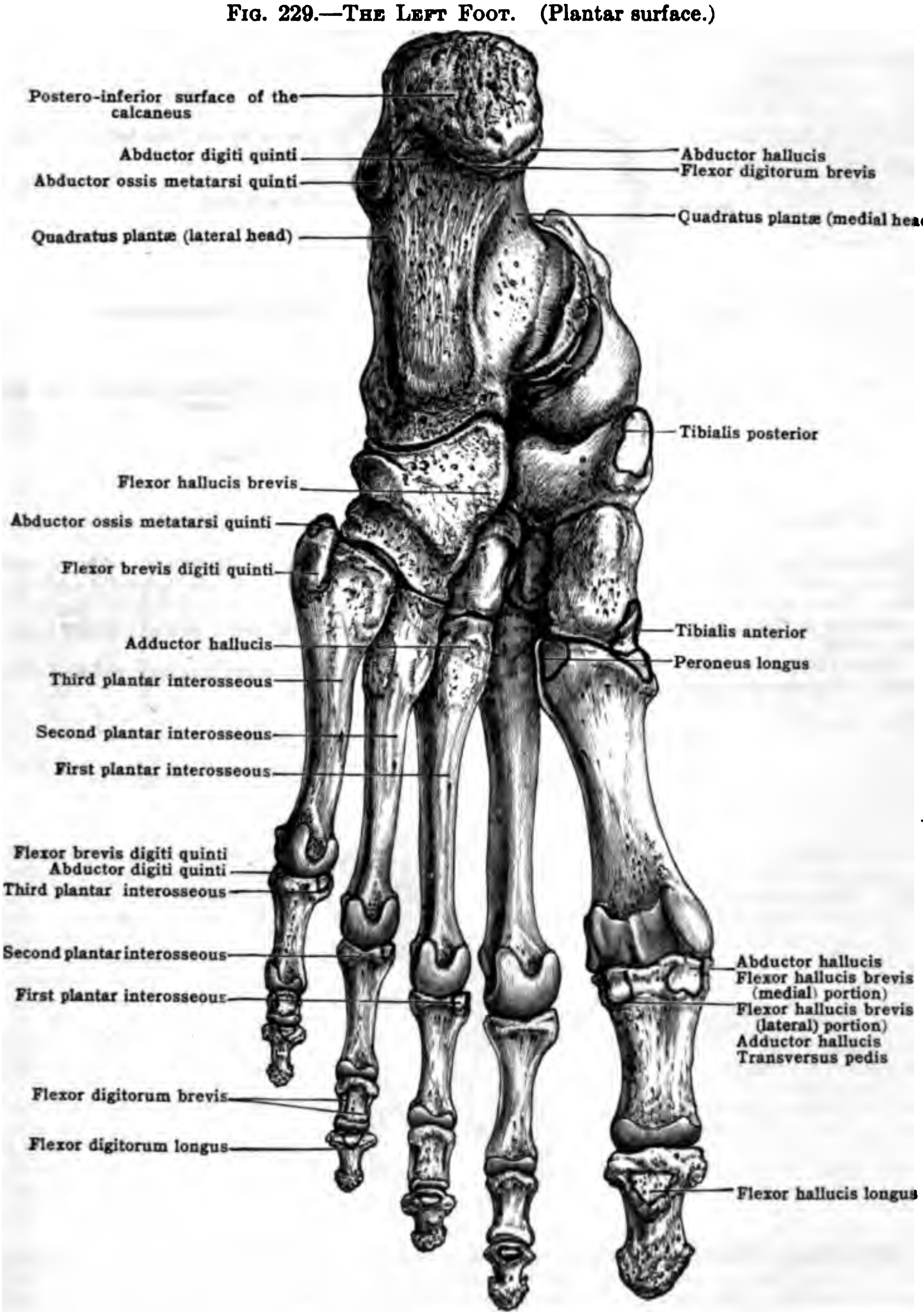
FIG. 228.—THE LEFT FOOT. (Superior surface.)



The **body** is somewhat quadrilateral in shape. The **upper surface** presents a broad, smooth surface for the tibia, slightly concave from side to side, convex from before backward, and wider in front than behind. The diminution in width posteriorly is associated with an obliquity of the lateral margin, which is directed medially as well as backward and downward. The **inferior surface** is occupied by a transversely disposed oblong facet [facies articularis calcanea

posterior], deeply concave from side to side, which articulates with a corresponding surface on the calcaneus. Of the malleolar surfaces, the lateral is almost entirely occupied by a large triangular facet, broad above, where it is continuous with the superior surface, concave from above downward, for articulation with the lateral malleolus; on the **medial malleolar surface** is a pyriform facet continuous with the superior surface, broad in front and narrow behind, which articulates with the medial malleolus. Below this facet the medial surface is rough for the attachment of the deep fibres of the deltoid (internal lateral) ligament of the ankle. The

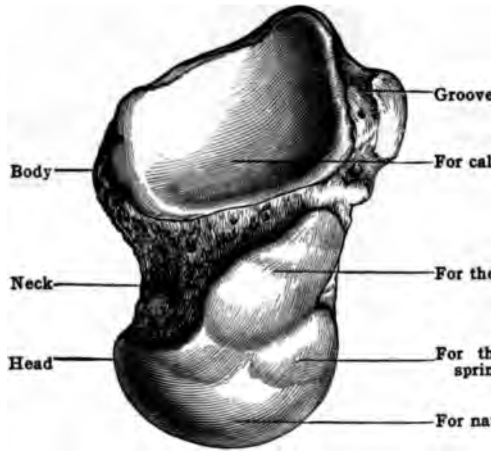
FIG. 229.—THE LEFT FOOT. (Plantar surface.)



superior surface and the two malleolar surfaces together constitute the **trochlea**. The **posterior surface** is of small extent and marked by a groove which lodges the tendon of the *flexor hallucis longus*. Bounding the groove on either side are two tubercles, of which the lateral [processus posterior tali] is usually the more prominent, for attachment of the posterior talo-fibular ligament of the ankle-joint; the medial tubercle gives attachment to the medial talo-calcaneal ligament. Continuous with the anterior aspect of the body is the neck, a con-

stricted part of the bone supporting the head. Above it is rough, and perforated by numerous vascular foramina. Below, it presents a deep groove [sulcus tali], directed from behind forward and lateralward. When the talus is articulated with the calcaneus, this furrow is converted into a canal [sinus tarsi] in which is lodged the interosseous talo-calcaneal ligament. The **head** is the rounded anterior end of the bone, and its large articular surface is divisible into three parts: in front, a smooth, oval convex area, directed downward and forward for the navicular bone; below, an elongated facet, convex from front to back, for articulation with the sustentaculum tali of the calcaneus; and between these, is a small facet which rests on the calcaneo-

Fig. 230.—The Left Talus. (Plantar view.)

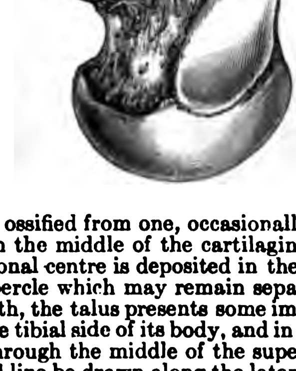


navicular ligament, separated from it by the synovial membrane of the talo-calcaneo-navicular joint.

Articulations.—The talus articulates with four bones and two ligaments. Above and medially with the tibia, below with the calcaneus, in front with the navicular, laterally with the fibula. The head articulates with the calcaneo-navicular ligament and the lateral border of the superior surface, at its posterior part, with the transverse ligament of the inferior tibio-fibular joint.

The talus is a very vascular bone and is nourished by the dorsalis pedis artery and its tarsal branch. It gives attachment to no muscles.

Fig. 231.—A Talus with the Os Trigonum.



Ossification.—The talus is ossified from one, occasionally from two, nuclei. The principal centre for this bone appears in the middle of the cartilaginous talus at the seventh month of intra-uterine life. The additional centre is deposited in the posterior portion of the bone, and forms the lateral posterior tubercle which may remain separate from the rest of the bone and form the **os trigonum**. At birth, the talus presents some important peculiarities in the disposition of the articular facet on the tibial side of its body, and in the obliquity of its neck. If, in the adult talus, a line be drawn through the middle of the superior trochlear surface parallel with its medial border, and a second line be drawn along the lateral side of the neck of the bone so as to intersect the first, the angle formed by these two lines will express the obliquity of the neck of the bone. This in the adult varies greatly, but the average may be taken as 10°. In the

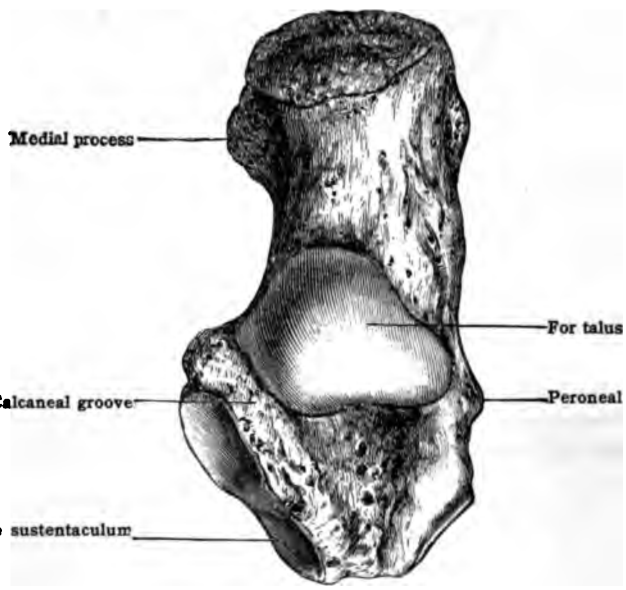
fœtus at birth the angle averages 35°, whilst in a young orang it measures 45°. In the normal adult talus the articular surface on the tibial side is limited to the body of the bone. In the fœtal talus it extends for some distane on to the neck, and sometimes reaches almost as far forward as the navicular facet on the head of the bone. This disposition of the medial malleolar facet is a characteristic feature of the talus in the chimpanzee and the orang. It is related to the inverted position of the foot which is found in the human fœtus almost up to the period of birth, and is of interest to the surgeon in connection with some varieties of club-foot. (Shattock and Parker.)

THE CALCANEUS

The **calcaneus** (or os calcis) (figs. 232, 233) is the largest and strongest bone of the foot. It is of an elongated form, flattened from side to side, and expanded at its posterior extremity, which projects downward and backward to form the heel. It presents six surfaces, superior, inferior lateral, medial, anterior and posterior.

The **superior surface** presents in the middle a large, oval, convex, articular facet for the under aspect of the body of the talus. In front of the facet the bone is marked by a deep

FIG. 232.—THE LEFT CALCANEUS. (Dorsal view.)



depression, the floor of which is rough for the attachment of ligaments, especially the talo-calcaneal, and the origin of the *extensor digitorum brevis* muscle; when the calcaneus and talus are articulated, this portion of the bone forms the floor of a cavity called the **sinus tarsi**. Medially, the upper surface of the bone presents a well-marked process, the **sustentaculum tali**, furnished with an elongated concave facet, occasionally divided into two, for articulation with the under aspect of the head of the talus. The posterior part of the upper surface is non-articular, convex from side to side, and in relation with a mass of fat placed in front of the tendo Achillis.

The **inferior surface** is narrow, rough, uneven, and ends posteriorly in two **processes**: the **medial** is the larger and broader, the **lateral** is narrower but prominent. The medial process affords origin to the *abductor hallucis*, the *flexor digitorum brevis*, and the *abductor digiti quinti;* the last muscle also arises from the lateral process and from the ridge of bone between. The rough surface in front of the tubercles gives attachment to the long plantar ligament (calcaneo-cuboid) and the lateral head of the *quadratus plantæ*. Near its anterior end this surface forms a rounded eminence, the **anterior tubercle**, from which (as well as from the shallow groove in front) the plantar (short) calcaneo-cuboid ligament arises. (According to the BNA nomenclature, the medial and lateral processes belong to the *tuber calcanei* or the posterior extremity of the bone.)

The **lateral surface** is broad, flat, and slightly convex. It represents near the middle a small eminence for the calcaneo-fibular ligament of the ankle-joint. Below and in front of this is a well-marked tubercle—the **trochlear process** [processus trochlearis] (or peroneal tubercle), separating two grooves, the upper for the *peroneus brevis* and the lower for the *peroneus longus*.

The **medial surface** is deeply concave, the hollow being increased by the prominent medial process behind and the overhanging **sustentaculum tali** in front. The latter forms a prominence of bone projecting horizontally, concave and articular above, grooved below for the tendon of the *flexor hallucis longus*, and giving attachment to a slip of the tendon of the *tibialis posterior*, the inferior calcaneo-navicular ligament, and some fibres of the deltoid ligament of the ankle-joint. The hollow below the process receives the plantar vessels and nerves and its lower part gives attachment to the medial head of the *quadratus plantæ*.

The **anterior surface** is somewhat quadrilateral in outline with rounded angles, and presents a saddle-shaped articular surface for the cuboid.

The **posterior surface** is oval in shape, rough, and convex. It is divided into three parts:—an upper, smooth and separated by a bursa from the tendo Achillis; a middle part giving attachment to the *tendo Achillis* and the *plantaris*, and a lower part in relation to the skin and fat of the heel. The expanded posterior extremity of the bone is known as the **tuber calcanei.**

Articulations.—The calcaneus articulates with two bones, the talus above and the cuboid in front.

Blood-supply.—The calcaneus is nourished by numerous branches from the posterior tibial and the medial and lateral malleolar arteries. They enter the bone chiefly on the inferior and medial surfaces.

FIG. 233.—THE CALCANEUS AT THE FIFTEENTH YEAR, SHOWING THE EPIPHYSIS.

Ossification.—The primary nucleus appears in the sixth month of intra-uterine life. The epiphysis, for its posterior extremity, begins to be ossified in the tenth year and is united to the body of the bone by the sixteenth year. It may extend over the whole of the posterior surface, as shown in fig. 233, or over the lower two-thirds only, leaving a part above in relation to the bursa beneath the tendo Achillis, which is formed from the primary nucleus. The medial and lateral processes are formed by the epiphysis.

THE NAVICULAR

The **navicular** [os naviculare pedis] (figs. 234, 235) is oval in shape, flattened from before backward, and situated between the talus behind and the three cuneiform bones in front. It is characterised by a large oval, concave, articular

FIG. 234.—THE LEFT NAVICULAR. (Anterior view.)

facet on the **posterior surface,** which receives the head of the talus; a broad, rough, rounded eminence on the **medial surface,** named the **tuberosity** of the navicular, the lower part of which projects downward and gives insertion to the tendon of

FIG. 235.—THE LEFT NAVICULAR, SHOWING A FACET FOR THE CUBOID.

the *tibialis posterior;* and an oblong-shaped **anterior surface,** convex and divided by two vertical ridges into three facets which articulate with the three cuneiform ›nes. The **superior** (dorsal) **surface** is rough, convex, and slopes downward to

the tuberosity; the **inferior** (plantar) **surface** is irregular and rough for the attachment of the inferior calcaneo-navicular ligament, and the **lateral surface** is rough and sometimes presents a small articular surface for the cuboid.

Articulations.—With the talus behind, with the three cuneiform bones in front, and occasionally with the cuboid on its lateral aspect.

Ossification.—The nucleus for the navicular appears in the course of the fourth year. The tuberosity of the navicular, into which the *tibialis posterior* acquires its main insertion, occasionally develops separately, and sometimes remains distinct from the rest of the bone.

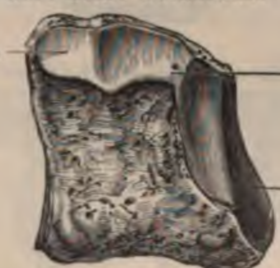
The Cuneiform Bones

Of the three cuneiform bones, the first is the largest, the second is the smallest, and the third intermediate in size. They are wedge-shaped bones placed between the navicular and the first, second and third metatarsal bones. Posteriorly, the ends of the bones lie in the same transverse line, but in front, the first and third project farther forward than the second, and form the sides of a deep recess into which the base of the second metatarsal bone is received.

Fig. 236.—The Left First Cuneiform. (Medial surface.)

The **first cuneiform** [os cuneiforme primum] (figs. 236, 237) is distinguished by its large size and by the fact that when articulated, the base of the wedge is directed downward and the apex upward. The **posterior surface** is concave and pyriform for articulation with the medial facet on the anterior surface of the navicular. The **anterior surface** forms a reniform articular facet for the base of the first metatarsal. The **medial surface** is rough, and presents an oblique groove for the tendon of the *tibialis anterior;* this groove is limited inferiorly by an oval facet into which a portion of the tendon is inserted. The **lateral surface** is concave and presents along its superior and posterior borders a reversed L-shaped facet for articulation with the second cuneiform, and, at its anterior extremity, with the second metatarsal. Anteriorly it is rough for ligaments. The **inferior surface** is rough for the insertion of the *peroneus longus, tibialis anterior,* and (usually) the *tibialis posterior.* The **superior surface** is the narrow part of the wedge and is directed upward.

Fig 237.—The Left First Cuneiform. (Lateral aspect.)



Articulations.—With the navicular behind, second cuneiform and second metatarsal on its lateral side, and first metatarsal in front.

Ossification.—From a single nucleus which appears in the course of the third year.

The **second cuneiform** [os cuneiforme secundum] (figs. 238, 239) is placed with the broad extremity upward and the narrow end downward, and is readily recognised by its nearly square base. The **posterior surface,** triangular and concave, articulates with the middle facet on the anterior surface of the navicular. The **anterior surface,** also triangular, but narrower than the posterior surface, articulates with the base of the second metatarsal. The **medial surface** has a reversed L-shaped facet running along its superior and posterior margins for articulation with the corresponding facet on the first cuneiform, and is rough elsewhere for the

attachment of ligaments. On the **lateral surface** near its posterior border is a vertical facet, sometimes bilobed, for the third cuneiform, and occasionally a second facet at the anterior inferior angle. The **superior surface** forms the square-cut base of the wedge and is rough for the attachment of ligaments. The **inferior surface** is sharp and rough for ligaments and a slip of the tendon of the *tibialis posterior*.

Fig. 238.—The Left Second Cuneiform. (Medial surface.)

Articulations.—With the navicular behind, second metatarsal in front, third cuneiform on the lateral side, and first cuneiform on the medial side.

Ossification.—From a single nucleus which appears in the fourth year.

The **third cuneiform bone** (figs. 240, 241) also placed with the broad end directed upward and the narrow end downward, is distinguished by the oblong shape of its base. Like the

Fig. 239.—The Left Second Cuneiform. (Lateral surface.)

second cuneiform, the **posterior surface** presents a triangular facet for the navicular; and the **anterior surface** a triangular facet, longer and narrower, for the third metatarsal. The **medial surface** has a large facet extending along the posterior border for the second cuneiform, and along the anterior border a narrow irregular facet for the lateral side of the base of the second metatarsal. Occasionally, a small facet is present near the anterior inferior angle for the second

Fig. 240.—The Left Third Cuneiform. (Medial surface.)

cuneiform. The **lateral surface** has a large distinctive facet near its posterior superior angle for the cuboid, and at the anterior superior angle there is usually a small facet for the medial side of the base of the fourth metatarsal. The **superior surface,** oblong in shape, is rough for ligaments, and the **inferior,** forming a rounded margin, receives a slip of the *tibialis posterior* and gives origin to a few fibres of the *flexor hallucis brevis*.

Fig. 241.—The Left Third Cuneiform. (Lateral surface.)

Articulations.—With the navicular behind, third metartarsal in front, cuboid and fourth metatarsal on the lateral side, second cuneiform and second metatarsal on the medial side.

Ossification.—A single nucleus appears in the course of the first year.

THE CUBOID

The **cuboid** (figs. 242, 243, 244), irregularly cubical in shape, is placed on the lateral aspect of the foot, forming a continuous line with the calcaneus and the fourth and fifth metatarsals.

Its **posterior surface** is somewhat quadrangular with rounded angles and presents a saddle-shaped articular surface for the calcaneus. Its lower and medial angle is somewhat prolonged backward beneath the sustentaculum tali (calcaneal process of the cuboid), an arrangement to oppose the upward or outward movement of the bone. This process occasionally terminates

FIG. 242.—THE LEFT CUBOID. (Medial view.)

in a rounded facet which plays on the head of the talus lateral to the facet for the calcaneo navicular ligament. The **anterior surface** is smaller and divided by a vertical ridge into two articular facets, a lateral for the base of the fifth, and a medial for the base of the fourth metatarsal. The **superior surface** is rough, non-articular, and directed obliquely upward. The **inferior surface** presents a prominent ridge for the attachment of the long plantar (calcaneo-cuboid) ligament, in front of which is a deep groove—the **peroneal groove**—running obliquely forward and medially and lodging the tendon of the *peroneus longus*. The ridge terminates laterally in an eminence, the **tuberosity** of the cuboid, on which there is usually a facet for a sesamoid bone of the tendon contained in the groove. The part of the surface behind the ridge is rough for the attachment of the plantar (short) calcaneo-cuboid ligament, a slip of the *tibialis posterior*, and a few fibres of the *flexor hallucis brevis*.

FIG. 243.—THE LEFT CUBOID. (Medial view.)

The **medial surface** presents, near its middle and upper part, an oval facet for articulation with the third cuneiform bone (fig. 242); behind this, a second facet for the navicular is frequently seen (fig. 243). Generally the two facets are confluent and then form an elliptical surface (fig. 244). The remainder of this surface is rough for the attachment of strong interosseous ligaments.

The **lateral surface,** the smallest and narrowest of all the surfaces, presents a deep notch which leads into the peroneal groove.

Articulations.—With the calcaneus behind, fourth and fifth metatarsals in front, third cuneiform and frequently the navicular on the medial side; occasionally also the talus.

FIG. 244.—THE LEFT CUBOID. (Medial view.)

Ossification.—The cuboid is ossified from a single nucleus which appears about the time of birth.

Accessory tarsal elements.—As in the carpus, a number of additional elements may occur in the tarsus. The most frequent of these is the **os trigonum,** which has already been noticed. Next in frequency is an additional first cuneiform, resulting from the ossification of the plantar half of that bone independently of the dorsal half, so that the bone is represented by a plantar and a dorsal first cuneiform. Other additional elements may occasionally occur at the upper posterior angle of the sustentaculum tali; at the anterior superior angle of the calcaneus, between that bone and the navicular; in the angle between the first cuneiform and the first and second metatarsals; and in the fibular angle between the fifth metatarsal and the cuboid (**os Vesalianum**).

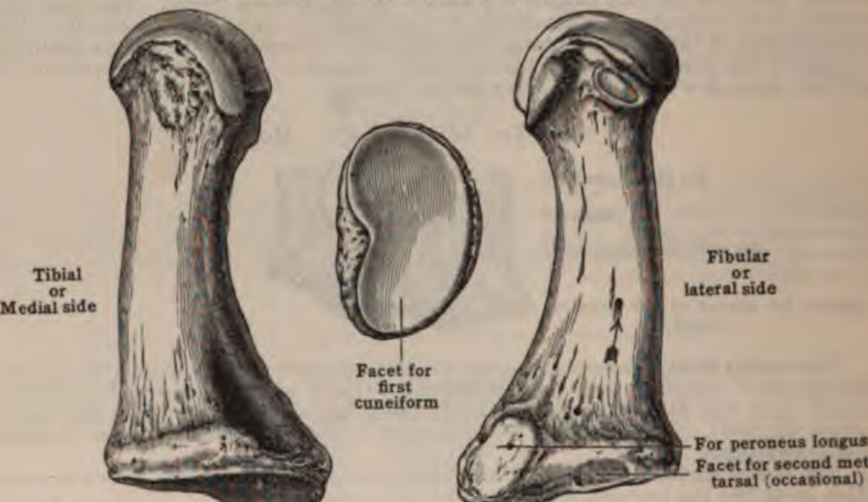
The fibular portion of the navicular is sometimes united to the cuboid and quite separate from the rest of the navicular, the cuboid in such cases articulating with the talus. This condition suggests the recognition of the fibular portion of the navicular as a distinct accessory tarsal element, the *cuboides secundarium*, though it has not yet been observed as an independent bone in the human foot.

THE METATARSUS

The **metatarsus** [ossa metatarsalia] consists of a series of five somewhat cylindrical bones. Articulated with the tarsus behind, they extend forward, nearly parallel with each other, to their anterior extremities, which articulate with the toes, and are numbered according to their position from great toe to small toe. Like the corresponding bones in the hand, each presents for examination a three-sided shaft, a proximal extremity termed the base, and a distal extremity or head. The shaft tapers gradually from the base to the head, and is slightly curved longitudinally so as to be convex on the dorsal and concave on the plantar aspect.

A typical metatarsal bone.—The **shaft** [corpus] is compressed laterally and presents for examination three borders and three surfaces. The two **borders,** distinguished as **medial** and **lateral,** are sharp and commence behind, one on each side of the dorsal aspect of the tarsal extremity, and, gradually approaching in the middle of the shaft, separate at the anterior end to terminate in the corresponding

Fig. 245.—The First (Left) Metatarsal.



tubercles. The **inferior border** is thick and rounded and extends from the under aspect of the tarsal extremity to near the anterior end of the bone, where it bifurcates, the two divisions terminating in the articular eminences on the plantar aspect of the head. Of the three surfaces, the **dorsal** is narrow in the middle and wider at either end. It is directed upward and is in relation with the extensor tendons. The **medial** and **lateral surfaces,** more extensive than the dorsal, corresponding with the interosseous spaces, are separated above, but meet together at the inferior border; they afford origin to the *interosseous* muscles. The **base** is wedge-shaped, articulating by its terminal surface with the tarsus, and on each side with the adjacent metatarsal bones. The dorsal and plantar surfaces are rough for the attachment of ligaments. The **head** presents a semicircular articular surface for the base of the first phalanx, and on each side a depression, surmounted by a tubercle, for the attachment of the lateral ligaments of the metatarso-phalangeal joint. The inferior surface of the head is grooved for the passage of the flexor tendons and is bounded by two eminences continuous with the terminal articular surface.

The several metatarsals possess distinctive characters by which they can be readily recognised.

The **first metatarsal** (fig. 245) is the most modified of all the metatarsal bones, and deviates widely from the general description given above. It is the shortest, the thickest, the strongest, and most massive of the series. The **base** presents a large reniform, slightly concave facet for the first cuneiform and projects downward into the sole to form the **tuberosity**, a rough eminence into which the *peroneus longus* and a slip of the *tibialis anterior* are inserted. A little

FIG. 246.—THE SECOND (LEFT) METATARSAL.

above the tuberosity, on its lateral side, there is occasionally a shallow, but easily recognised facet, for articulation with the base of the second metatarsal. The **head** is marked on the plantar surface by two deep grooves, separated by a ridge, in which the two sesamoid bones of the *flexor hallucis brevis* glide. The **shaft** is markedly prismatic. The **dorsal surface** is smooth, broad, and convex, directed obliquely upward; the **plantar surface** is concave longitudinally

FIG. 247.—THE THIRD (LEFT) METATARSAL.

and covered by the *flexor hallucis longus* and *brevis*, whilst the **lateral surface** is triangular in outline, almost vertical, and in relation with the first *dorsal interosseous* and *adductor hallucis obliquus*. A few fibres of the medial head of the first *dorsal interosseous* occasionally arise from the hinder part of the surface adjoining the base, or from the border separating the lateral from the dorsal surface. Somewhere near the middle of the shaft, and on its fibular side, is the nutrient foramen, directed toward the head of the bone.

The **anterior surface** is somewhat quadrilateral in outline with rounded angles, and presents a saddle-shaped articular surface for the cuboid.

The **posterior surface** is oval in shape, rough, and convex. It is divided into three parts:—an upper, smooth and separated by a bursa from the tendo Achillis; a middle part giving attachment to the *tendo Achillis* and the *plantaris*, and a lower part in relation to the skin and fat of the heel. The expanded posterior extremity of the bone is known as the **tuber calcanei**.

Articulations.—The calcaneus articulates with two bones, the talus above and the cuboid in front.

Blood-supply.—The calcaneus is nourished by numerous branches from the posterior tibial and the medial and lateral malleolar arteries. They enter the bone chiefly on the inferior and medial surfaces.

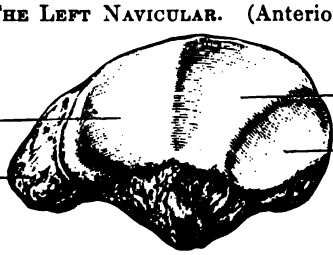
Fig. 233.—The Calcaneus at the Fifteenth Year, showing the Epiphysis.

Ossification.—The primary nucleus appears in the sixth month of intra-uterine life. The epiphysis, for its posterior extremity, begins to be ossified in the tenth year and is united to the body of the bone by the sixteenth year. It may extend over the whole of the posterior surface, as shown in fig. 233, or over the lower two-thirds only, leaving a part above in relation to the bursa beneath the tendo Achillis, which is formed from the primary nucleus. The medial and lateral processes are formed by the epiphysis.

The Navicular

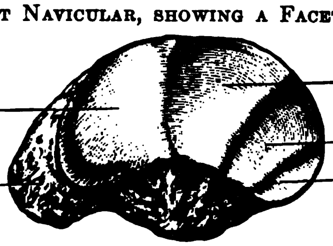
The **navicular** [os naviculare pedis] (figs. 234, 235) is oval in shape, flattened from before backward, and situated between the talus behind and the three cuneiform bones in front. It is characterised by a large oval, concave, articular

Fig. 234.—The Left Navicular. (Anterior view.)



facet on the **posterior surface**, which receives the head of the talus; a broad, rough, rounded eminence on the **medial surface**, named the **tuberosity** of the navicular, the lower part of which projects downward and gives insertion to the tendon of

Fig. 235.—The Left Navicular, showing a Facet for the Cuboid.



the *tibialis posterior;* and an oblong-shaped **anterior surface**, convex and divided by two vertical ridges into three facets which articulate with the three cuneiform bones. The **superior (dorsal) surface** is rough, convex, and slopes downward to

the tuberosity; the **inferior** (plantar) **surface** is irregular and rough for the attachment of the inferior calcaneo-navicular ligament, and the **lateral surface** is rough and sometimes presents a small articular surface for the cuboid.

Articulations.—With the talus behind, with the three cuneiform bones in front, and occasionally with the cuboid on its lateral aspect.

Ossification.—The nucleus for the navicular appears in the course of the fourth year. The tuberosity of the navicular, into which the *tibialis posterior* acquires its main insertion, occasionally develops separately, and sometimes remains distinct from the rest of the bone.

THE CUNEIFORM BONES

Of the three cuneiform bones, the first is the largest, the second is the smallest, and the third intermediate in size. They are wedge-shaped bones placed between the navicular and the first, second and third metatarsal bones. Posteriorly, the ends of the bones lie in the same transverse line, but in front, the first and third project farther forward than the second, and form the sides of a deep recess into which the base of the second metatarsal bone is received.

FIG. 236.—THE LEFT FIRST CUNEIFORM. (Medial surface.)

The **first cuneiform** [os cuneiforme primum] (figs. 236, 237) is distinguished by its large size and by the fact that when articulated, the base of the wedge is directed downward and the apex upward. The **posterior surface** is concave and pyriform for articulation with the medial facet on the anterior surface of the navicular. The **anterior surface** forms a reniform articular facet for the base of the first metatarsal. The **medial surface** is rough, and presents an oblique groove for the tendon of the *tibialis anterior;* this groove is limited inferiorly by an oval facet into which a portion of the tendon is inserted. The **lateral surface** is concave and presents along its superior and posterior borders a reversed L-shaped facet for articulation with the second cuneiform, and, at its anterior extremity, with the second metatarsal. Anteriorly it is rough for ligaments. The **inferior surface** is rough for the insertion of the *peroneus longus, tibialis anterior,* and (usually) the *tibialis posterior.* The superior surface is the narrow part of the wedge and is directed upward.

FIG 237.—THE LEFT FIRST CUNEIFORM. (Lateral aspect.)

Articulations.—With the navicular behind, second cuneiform and second metatarsal on its lateral side, and first metatarsal in front.

Ossification.—From a single nucleus which appears in the course of the third year.

The **second cuneiform** [os cuneiforme secundum] (figs. 238, 239) is placed with the broad extremity upward and the narrow end downward, and is readily recognised by its nearly square base. The **posterior surface,** triangular and concave, articulates with the middle facet on the anterior surface of the navicular. The **anterior surface,** also triangular, but narrower than the posterior surface, articulates with the base of the second metatarsal. The **medial surface** has a reversed L-shaped facet running along its superior and posterior margins for articulation with the corresponding facet on the first cuneiform, and is rough elsewhere for the

The **anterior surface** is somewhat quadrilateral in outline with rounded angles, and presents a saddle-shaped articular surface for the cuboid.

The **posterior surface** is oval in shape, rough, and convex. It is divided into three parts:—an upper, smooth and separated by a bursa from the tendo Achillis; a middle part giving attachment to the *tendo Achillis* and the *plantaris*, and a lower part in relation to the skin and fat of the heel. The expanded posterior extremity of the bone is known as the **tuber calcanei.**

Articulations.—The calcaneus articulates with two bones, the talus above and the cuboid in front.

Blood-supply.—The calcaneus is nourished by numerous branches from the posterior tibial and the medial and lateral malleolar arteries. They enter the bone chiefly on the inferior and medial surfaces.

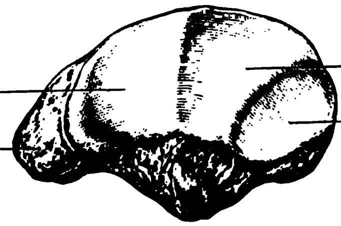
FIG. 233.—THE CALCANEUS AT THE FIFTEENTH YEAR, SHOWING THE EPIPHYSIS.

Ossification.—The primary nucleus appears in the sixth month of intra-uterine life. The epiphysis, for its posterior extremity, begins to be ossified in the tenth year and is united to the body of the bone by the sixteenth year. It may extend over the whole of the posterior surface, as shown in fig. 233, or over the lower two-thirds only, leaving a part above in relation to the bursa beneath the tendo Achillis, which is formed from the primary nucleus. The medial and lateral processes are formed by the epiphysis.

THE NAVICULAR

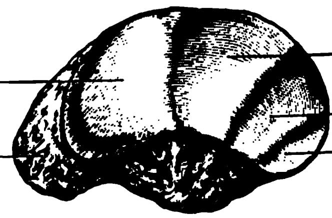
The **navicular** [os naviculare pedis] (figs. 234, 235) is oval in shape, flattened from before backward, and situated between the talus behind and the three cuneiform bones in front. It is characterised by a large oval, concave, articular

FIG. 234.—THE LEFT NAVICULAR. (Anterior view.)



facet on the **posterior surface,** which receives the head of the talus; a broad, rough, rounded eminence on the **medial surface,** named the **tuberosity** of the navicular, the lower part of which projects downward and gives insertion to the tendon of

FIG. 235.—THE LEFT NAVICULAR, SHOWING A FACET FOR THE CUBOID.



the *tibialis posterior;* and an oblong-shaped **anterior surface,** convex and divided by two vertical ridges into three facets which articulate with the three cuneiform bones. The **superior** (dorsal) **surface** is rough, convex, and slopes downward to

he tuberosity; the **inferior** (plantar) **surface** is irregular and rough for the attach-
ıent of the inferior calcaneo-navicular ligament, and the **lateral surface** is rough
.nd sometimes presents a small articular surface for the cuboid.

Articulations.—With the talus behind, with the three cuneiform bones in
ront, and occasionally with the cuboid on its lateral aspect.

Ossification.—The nucleus for the navicular appears in the course of the fourth year. The
uberosity of the navicular, into which the *tibialis posterior* acquires its main insertion, occasion-
lly develops separately, and sometimes remains distinct from the rest of the bone.

The Cuneiform Bones

Of the three cuneiform bones, the first is the largest, the second is the smallest,
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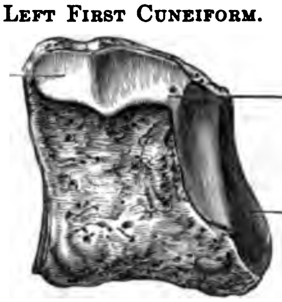
he navicular and the first, second and third metatarsal bones. Posteriorly, the
ınds of the bones lie in the same transverse line, but in front, the first and third
ıroject farther forward than the second, and form the sides of a deep recess into
vhich the base of the second metatarsal bone is received.

Fig. 236.—The Left First Cuneiform. (Medial surface.)

The **first cuneiform** [os cuneiforme primum] (figs. 236, 237) is distinguished by its **large**
ize and by the fact that when articulated, the base of the wedge is directed downward and the
pex upward. The **posterior surface** is concave and pyriform for articulation with the medial
ıcet on the anterior surface of the navicular. The **anterior surface** forms a reniform articular
ıcet for the base of the first metatarsal. The **medial surface** is rough, and presents an oblique
roove for the tendon of the *tibialis anterior;* this groove is limited inferiorly by an oval facet
ıto which a portion of the tendon is inserted. The **lateral surface** is concave and presents along
ıs superior and posterior borders a reversed L-shaped facet for articulation with the second
uneiform, and, at its anterior extremity, with the second metatarsal. Anteriorly it is rough
ɔr ligaments. The **inferior surface** is rough for the insertion of the *peroneus longus, tibialis
nterior,* and (usually) the *tibialis posterior*. The superior **surface** is the narrow part of the
ʼedge and is directed upward.

Fig 237.—The Left First Cuneiform. (Lateral aspect.)



Articulations.—With the navicular behind, second cuneiform and second metatarsal on
ːs lateral side, and first metatarsal in front.

Ossification.—From a single nucleus which appears in the course of the third year.

The **second cuneiform** [os cuneiforme secundum] (figs. 238, 239) is placed with the broad
xtremity upward and the narrow end downward, and is readily recognised by its nearly
quare base. The **posterior surface,** triangular and concave, articulates with the middle facet
n the anterior surface of the navicular. The **anterior surface,** also triangular, but narrower
han the posterior surface, articulates with the base of the second metatarsal. The **medial
urface** has a reversed L-shaped facet running along its superior and posterior margins for
rticulation with the corresponding facet on the first cuneiform, and is rough elsewhere for the

attachment of ligaments. On the **lateral surface** near its posterior border is a vertical facet, sometimes bilobed, for the third cuneiform, and occasionally a second facet at the anterior inferior angle. The **superior surface** forms the square-cut base of the wedge and is rough for the attachment of ligaments. The **inferior surface** is sharp and rough for ligaments and a slip of the tendon of the *tibialis posterior*.

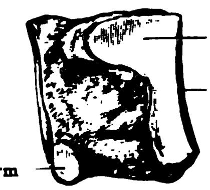
FIG. 238.—THE LEFT SECOND CUNEIFORM. (Medial surface.)

Articulations.—With the navicular behind, second metatarsal in front, third cuneiform on the lateral side, and first cuneiform on the medial side.

Ossification.—From a single nucleus which appears in the fourth year.

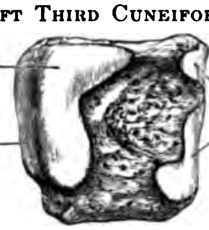
The **third cuneiform bone** (figs. 240, 241) also placed with the broad end directed upward and the narrow end downward, is distinguished by the oblong shape of its base. Like the

FIG. 239.—THE LEFT SECOND CUNEIFORM. (Lateral surface.)



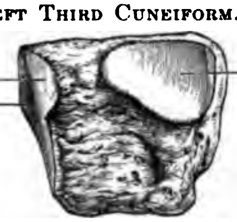
second cuneiform, the **posterior surface** presents a triangular facet for the navicular; and the **anterior surface** a triangular facet, longer and narrower, for the third metatarsal. The **medial surface** has a large facet extending along the posterior border for the second cuneiform, and along the anterior border a narrow irregular facet for the lateral side of the base of the second metatarsal. Occasionally, a small facet is present near the anterior inferior angle for the second

FIG. 240.—THE LEFT THIRD CUNEIFORM. (Medial surface.)



cuneiform. The **lateral surface** has a large distinctive facet near its posterior superior angle for the cuboid, and at the anterior superior angle there is usually a small facet for the medial side of the base of the fourth metatarsal. The **superior surface,** oblong in shape, is rough for ligaments, and the **inferior,** forming a rounded margin, receives a slip of the *tibialis posterior* and gives origin to a few fibres of the *flexor hallucis brevis*.

FIG. 241.—THE LEFT THIRD CUNEIFORM. (Lateral surface.)



Articulations.—With the navicular behind, third metartarsal in front, cuboid and fourth metatarsal on the lateral side, second cuneiform and second metatarsal on the medial side.

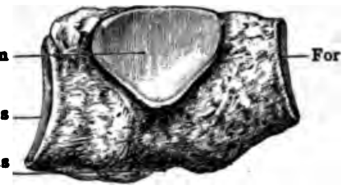
Ossification.—A single nucleus appears in the course of the first year.

THE CUBOID

The **cuboid** (figs. 242, 243, 244), irregularly cubical in shape, is placed on the lateral aspect of the foot, forming a continuous line with the calcaneus and the fourth and fifth metatarsals.

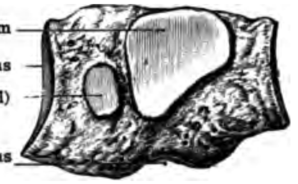
Its **posterior surface** is somewhat quadrangular with rounded angles and presents a saddle-shaped articular surface for the calcaneus. Its lower and medial angle is somewhat prolonged backward beneath the sustentaculum tali (calcaneal process of the cuboid), an arrangement to oppose the upward or outward movement of the bone. This process occasionally terminates

FIG. 242.—THE LEFT CUBOID. (Medial view.)



in a rounded facet which plays on the head of the talus lateral to the facet for the calcaneo navicular ligament. The **anterior surface** is smaller and divided by a vertical ridge into two articular facets, a lateral for the base of the fifth, and a medial for the base of the fourth metatarsal. The **superior surface** is rough, non-articular, and directed obliquely upward. The **inferior surface** presents a prominent ridge for the attachment of the long plantar (calcaneo-cuboid) ligament, in front of which is a deep groove—the **peroneal groove**—running obliquely forward and medially and lodging the tendon of the *peroneus longus*. The ridge terminates laterally in an eminence, the **tuberosity** of the cuboid, on which there is usually a facet for a sesamoid bone of the tendon contained in the groove. The part of the surface behind the ridge is rough for the attachment of the plantar (short) calcaneo-cuboid ligament, a slip of the *tibialis posterior*, and a few fibres of the *flexor hallucis brevis*.

FIG. 243.—THE LEFT CUBOID. (Medial view.)

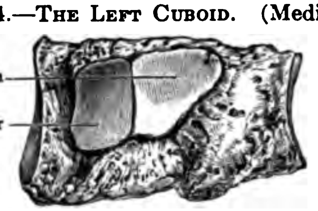


The **medial surface** presents, near its middle and upper part, an oval facet for articulation with the third cuneiform bone (fig. 242); behind this, a second facet for the navicular is frequently seen (fig. 243). Generally the two facets are confluent and then form an elliptical surface (fig. 244). The remainder of this surface is rough for the attachment of strong interosseous ligaments.

The **lateral surface**, the smallest and narrowest of all the surfaces, presents a deep notch which leads into the peroneal groove.

Articulations.—With the calcaneus behind, fourth and fifth metatarsals in front, third cuneiform and frequently the navicular on the medial side; occasionally also the talus.

FIG. 244.—THE LEFT CUBOID. (Medial view.)



Ossification.—The cuboid is ossified from a single nucleus which appears about the time of birth.

Accessory tarsal elements.—As in the carpus, a number of additional elements may occur in the tarsus. The most frequent of these is the **os trigonum**, which has already been noticed. Next in frequency is an additional first cuneiform, resulting from the ossification of the plantar half of that bone independently of the dorsal half, so that the bone is represented by a plantar and a dorsal first cuneiform. Other additional elements may occasionally occur at the upper posterior angle of the sustentaculum tali; at the anterior superior angle of the calcaneus, between that bone and the navicular; in the angle between the first cuneiform and the first and second metatarsals; and in the fibular angle between the fifth metatarsal and the cuboid (**os Vesalianum**).

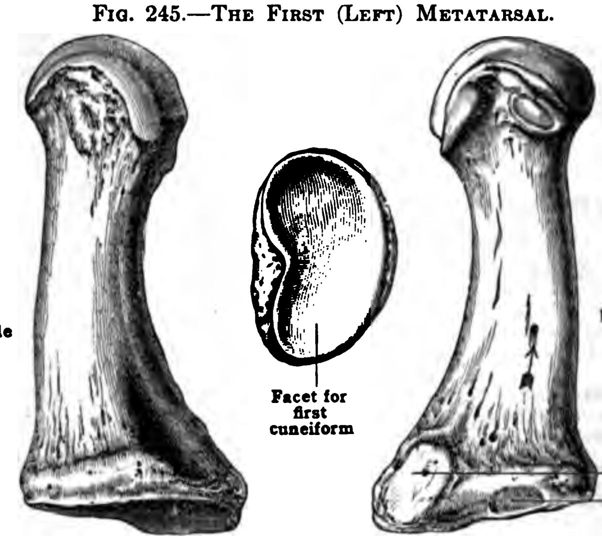
The fibular portion of the navicular is sometimes united to the cuboid and quite separate from the rest of the navicular, the cuboid in such cases articulating with the talus. This condition suggests the recognition of the fibular portion of the navicular as a distinct accessory tarsal element, the *cuboides secundarium,* though it has not yet been observed as an independent bone in the human foot.

THE METATARSUS

The **metatarsus** [ossa metatarsalia] consists of a series of five somewhat cylindrical bones. Articulated with the tarsus behind, they extend forward, nearly parallel with each other, to their anterior extremities, which articulate with the toes, and are numbered according to their position from great toe to small toe. Like the corresponding bones in the hand, each presents for examination a three-sided shaft, a proximal extremity termed the base, and a distal extremity or head. The shaft tapers gradually from the base to the head, and is slightly curved longitudinally so as to be convex on the dorsal and concave on the plantar aspect.

A typical metatarsal bone.—The **shaft** [corpus] is compressed laterally and presents for examination three borders and three surfaces. The two **borders,** distinguished as **medial** and **lateral,** are sharp and commence behind, one on each side of the dorsal aspect of the tarsal extremity, and, gradually approaching in the middle of the shaft, separate at the anterior end to terminate in the corresponding

FIG. 245.—THE FIRST (LEFT) METATARSAL.

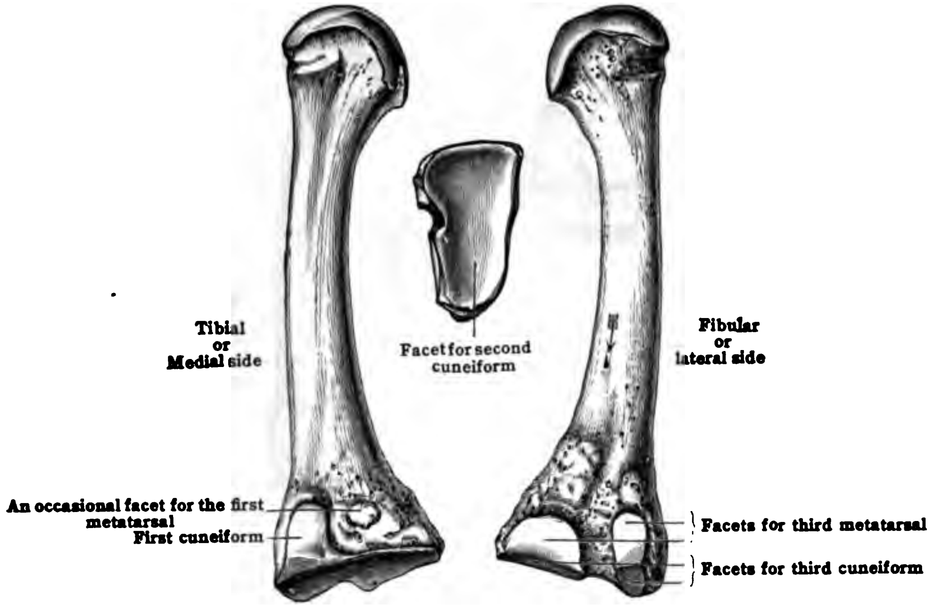


tubercles. The **inferior border** is thick and rounded and extends from the under aspect of the tarsal extremity to near the anterior end of the bone, where it bifurcates, the two divisions terminating in the articular eminences on the plantar aspect of the head. Of the three surfaces, the **dorsal** is narrow in the middle and wider at either end. It is directed upward and is in relation with the extensor tendons. The **medial** and **lateral surfaces,** more extensive than the dorsal, corresponding with the interosseous spaces, are separated above, but meet together at the inferior border; they afford origin to the *interosseous* muscles. The **base** is wedge-shaped, articulating by its terminal surface with the tarsus, and on each side with the adjacent metatarsal bones. The dorsal and plantar surfaces are rough for the attachment of ligaments. The **head** presents a semicircular articular surface for the base of the first phalanx, and on each side a depression, surmounted by a tubercle, for the attachment of the lateral ligaments of the metatarso-phalangeal joint. The inferior surface of the head is grooved for the passage of the flexor tendons and is bounded by two eminences continuous with the terminal articular surface.

The several metatarsals possess distinctive characters by which they can be readily recognised.

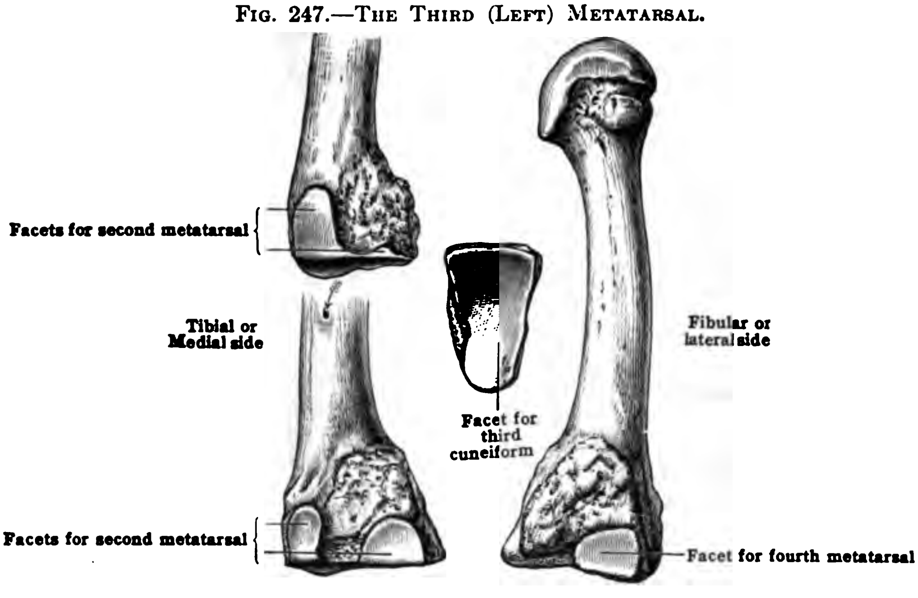
The **first metatarsal** (fig. 245) is the most modified of all the metatarsal bones, and deviates widely from the general description given above. It is the shortest, the thickest, the strongest, and most massive of the series. The **base** presents a large reniform, slightly concave facet for the first cuneiform and projects downward into the sole to form the **tuberosity**, a rough eminence into which the *peroneus longus* and a slip of the *tibialis anterior* are inserted. A little

FIG. 246.—THE SECOND (LEFT) METATARSAL.



above the tuberosity, on its lateral side, there is occasionally a shallow, but easily recognised facet, for articulation with the base of the second metatarsal. The **head** is marked on the plantar surface by two deep grooves, separated by a ridge, in which the two sesamoid bones of the *flexor hallucis brevis* glide. The shaft is markedly prismatic. The **dorsal surface** is smooth, broad, and convex, directed obliquely upward; the **plantar surface** is concave longitudinally

FIG. 247.—THE THIRD (LEFT) METATARSAL.



and covered by the *flexor hallucis longus* and *brevis*, whilst the **lateral surface** is triangular in outline, almost vertical, and in relation with the first *dorsal interosseous* and *adductor hallucis obliquus*. A few fibres of the medial head of the first *dorsal interosseous* occasionally arise from the hinder part of the surface adjoining the base, or from the border separating the lateral from the dorsal surface. Somewhere near the middle of the shaft, and on its fibular side, is the nutrient foramen, directed toward the head of the bone.

The **second metatarsal** (fig. 246) is the longest of the series. Its base is prolonged backward to occupy the space between the first and third cuneiform, and accordingly it is marked by facets for articulation with each of these bones. The tarsal surface is triangular in outline, with the base above and apex below, and articulates with the second cuneiform bone. On the tibial side of the base, near the upper angle, is a small facet for the first cuneiform, and occasionally another for the first metatarsal a little lower down. The fibular side of the base presents an upper and a lower facet, separated by a non-articular depression, and each facet is divided by a vertical ridge into two, thus making four in all. The two posterior facets articulate with the third cuneiform and the two anterior with the third metatarsal. The base gives attachment to a slip of the *tibialis posterior* and the *adductor hallucis obliquus*, whilst from the shaft the first and second *dorsal interosseous* muscles take origin. The nutrient foramen is situated on the fibular side of the shaft near the middle and is directed toward the base of the bone.

FIG. 248.—THE FOURTH (LEFT) METATARSAL.

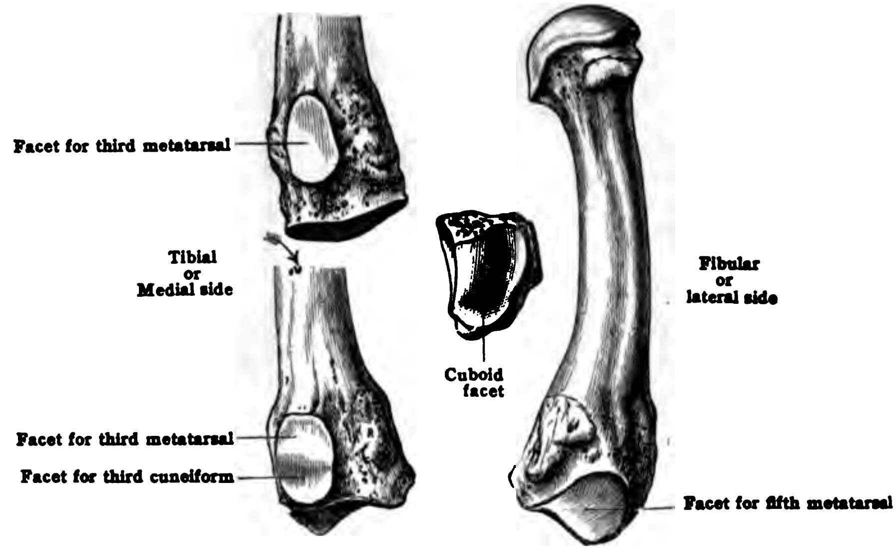
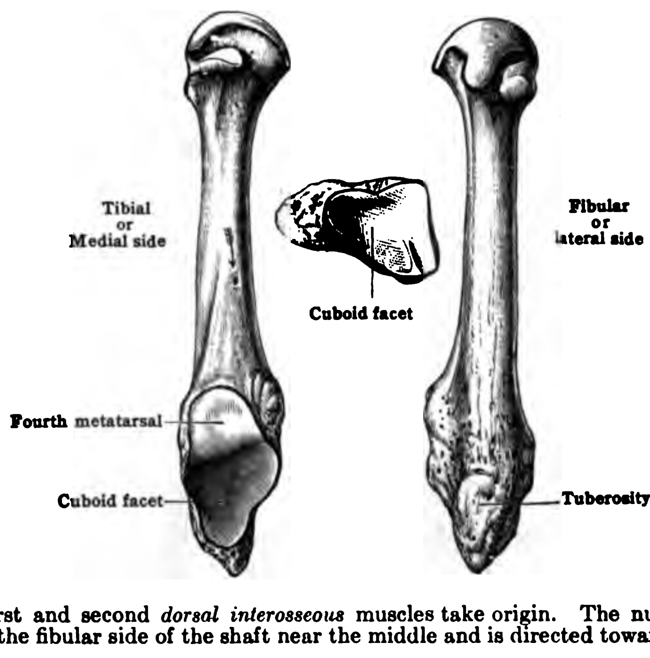


FIG. 249.—THE FIFTH (LEFT) METATARSAL.



The **third metatarsal** (fig. 247), a little shorter than the second, articulates by the triangular surface of its base with the third cuneiform. On the medial side are two small facets, one below the other, for the second metatarsal, and on the lateral side, a single large facet for the fourth metatarsal. The base gives attachment to a slip of the *tibialis posterior* and the *adductor hallucis obliquus*, and from the shaft three *interosseous* muscles take origin. The nutrient foramen is situated on the tibial side of the shaft and is directed toward the base.

The **fourth metatarsal** (fig. 248), smaller in size than the preceding, is distinguished by he quadrilateral facet on the base, for the cuboid. The medial side presents a large facet ivided by a ridge into an anterior portion for articulation with the third metatarsal and a osterior portion for the third cuneiform. Occasionally the cuneiform part of the facet is ranting. On the lateral side of the base is a single facet for articulation with the fifth netatarsal.

The **fifth metatarsal** (fig. 249), is shorter than the fourth, but longer than the first. It is ecognised by the large nipple-shaped process, known as the **tuberosity**, which projects on the ateral side of the base. It constitutes the hindmost part of the bone and gives insertion to he *peroneus brevis* on the dorsal aspect, and *flexor brevis digiti quinti* and the occasional *bductor ossis metatarsi quinti* on the plantar aspect. The fifth metatarsal articulates behind y an obliquely directed triangular facet with the cuboid, and on the medial side with the ourth metatarsal. The plantar aspect of the base is marked by a shallow groove which odges the tendon of the *abductor digiti quinti*, and the dorsal surface, continuous with the uperior surface of the shaft, receives the insertion of the *peroneus tertius*. The **head** is small nd turned somewhat laterally in consequence of the curvature of the shaft in the same lirection. The **shaft** differs from that of any of the other metatarsals in being compressed rom above downward, instead of from side to side, so as to present superior, inferior, and nedial surfaces. It gives origin to the lateral head of the fourth *dorsal interosseous* and the hird *plantar interosseous* muscles. The nutrient foramen is situated on its tibial side and is lirected toward the base.

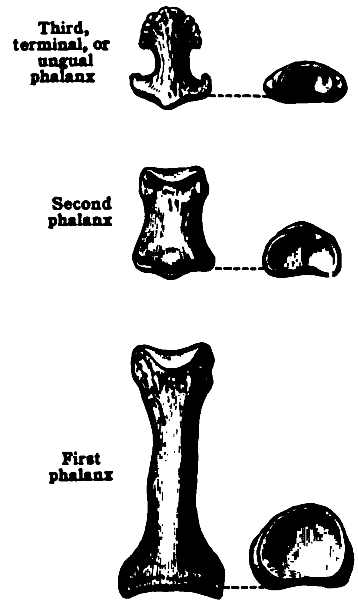
Ossification.—Each metatarsal ossifies from two centres. The primary nucleus for the haft appears in the eighth week of embryonic life in the middle of the cartilaginous metatarsal. At birth, each extremity is represented by cartilage, and that at the proximal end is ossified by xtension from the primary nucleus, except in the case of the first metatarsal. For this, a nucleus appears in the third year.

The distal ends of the four lateral metatarsals are ossified by secondary nuclei which make heir appearance about the third year. Very frequently an epiphysis is found at the distal end f the first metatarsal as well as at its base. The shafts and epiphyses consolidate at the twenieth year. The sesamoids belonging to the *flexor hallucis brevis* begin to ossify about the fifth ear.

THE PHALANGES

The **phalanges** (fig. 250) are the bones of the toes, and number in all fourteen. Except the great toe, each consists of three phalanges, distinguished as first proximal), second and third (distal); in the great toe the second phalanx is absent.

FIG. 250.—THE PHALANGES OF THE MIDDLE TOE.



There is thus a similarity as regards number and general arrangement with the phalanges of the fingers. With the exception of the phalanges of the great toe, which are larger than those of the thumb, the bones of the toes are smaller and more rudimentary than the corresponding bones of the fingers. In all the phalanges, the nutrient foramen is directed toward the distal extremity.

The phalanges of the **first** row are constricted in the middle and expanded at either extremity. The shafts are narrow and laterally compressed, rounded on the dorsal and concave

on the plantar aspects. The base of each presents a single oval concave facet for the convex head of the corresponding metatarsal, whilst the head forms a pulley-like surface [trochlea phalangis], grooved in the centre and elevated on each side for the second phalanx.

The phalanges of the **second row** are stunted, insignificant bones. Their **shafts**, besides being much shorter, are flatter than those of the first row. The **bases** have two depressions, separated by a vertical ridge, and the heads present **trochlear** surfaces for the ungual phalanges.

The **third**, or **ungual** phalanges are easily recognised. The bases articulate with the second phalanges; the shafts are expanded, forming the ungual tuberosities which support the nails, and their plantar surfaces are rough where they come into relation with the pulp of the digits.

The muscles attached to the various phalanges may be tabulated thus:—

The **first phalanx of the hallux** gives insertion to the flexor hallucis brevis; abductor hallucis; adductor hallucis transversus and obliquus; extensor digitorum brevis.

The **first phalanx of second toe**: The first and second dorsal interosseous.

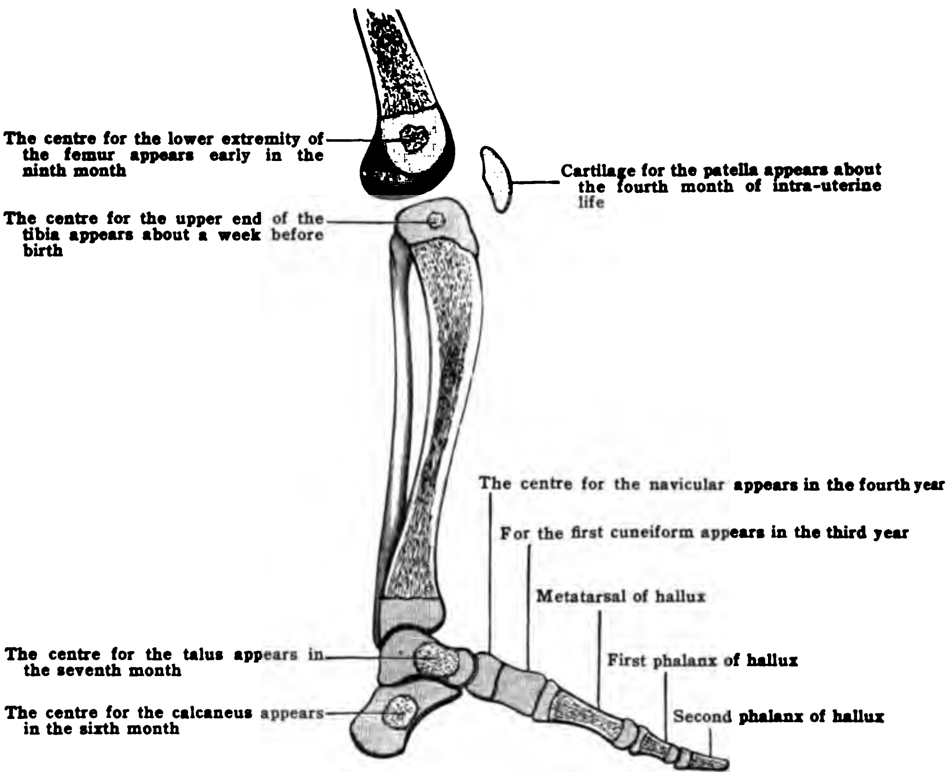
The **first phalanx of third toe**: Third dorsal interosseous; first plantar interosseous.

The **first phalanx of fourth toe**: Second plantar interosseous; fourth dorsal interosseous.

The **first phalanx of fifth toe**: Third plantar interosseous; flexor digiti quinti brevis; and abductor digiti quinti.

The **terminal phalanx of hallux**: Flexor hallucis longus; extensor hallucis longus.

FIG. 251.—A LONGITUDINAL SECTION OF THE BONES OF THE LOWER LIMB AT BIRTH.



The **second phalanges of the remaining toes**: Dorsal expansion of the extensor tendons, including extensor digitorum longus, extensor digitorum brevis (except in the case of the fifth toe), and expansions from the interossei and lumbricales.

The **third phalanges**: Flexor digitorum longus; dorsal expansion of the extensor tendon with the associated muscles.

Ossification.—Like the corresponding bones of the fingers, the phalanges of the toes ossify from a primary and a secondary nucleus. In each, the centre for the shaft appears during the eighth or ninth week of embryonic life. The secondary centre forms a scale-like epiphysis for the proximal end between the fourth and eighth years, and union takes place in the eighteenth or nineteenth year—i. e., earlier than the corresponding epiphyses in the fingers. The primary centres for the third phalanges appear at the distal extremities of the bones.

SESAMOID BONES

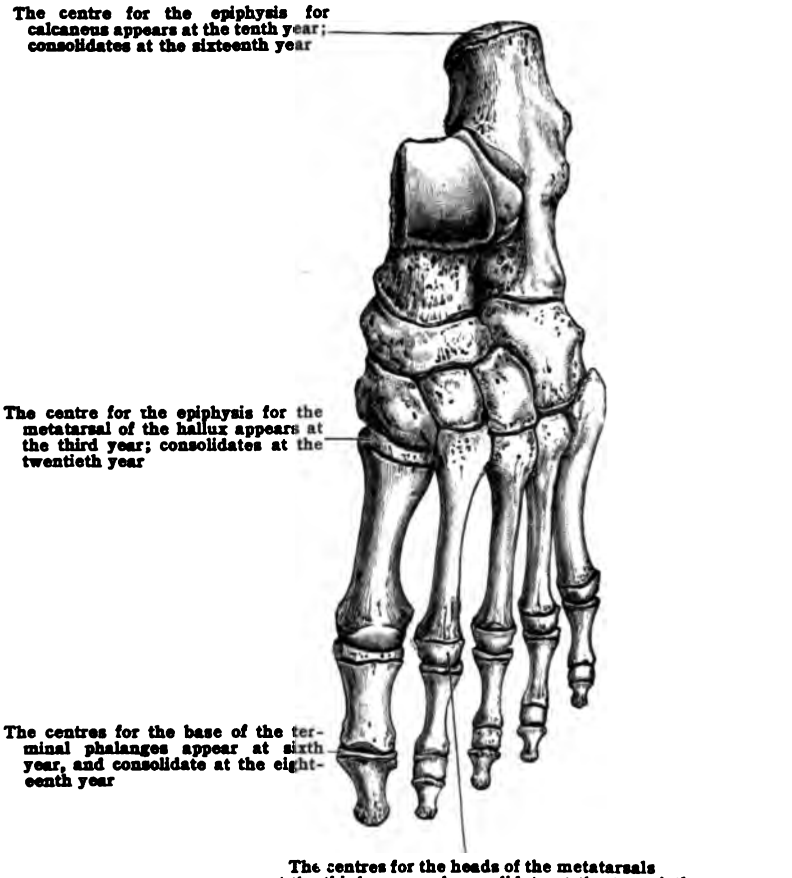
In the foot a pair of sesamoid bones is constant over the metatarso-phalangeal joint of the great toe in the tendons of the flexor hallucis brevis. One sometimes occurs over the interphalangeal joint of the same toe and over the metatarso-phalangeal joints of the second and fifth and rarely of the third and fourth toes.

A sesamoid also occurs in the tendon of the peroneus longus, where it glides over the groove in the cuboid; another may be found, especially in later life, in the tendon of the tibialis anterior over the first cuneiform bone, and another in the tendon of the tibialis posterior over the medial surface of the head of the talus. Further a sesamoid, the fabella, sometimes occurs in the lateral head of the gastrocnemius, and another may be found in the tendon of the ilio-psoas over the pubis.

BONES OF THE FOOT AS A WHOLE

Although the foot is constructed on the same general plan as the hand, there is a marked difference in its architecture to qualify it for the different functions which it is called upon to perform. When in the erect posture, the foot forms a firm basis of support for the rest of the body, and the bones are arranged in an elliptical arch, supported on two pillars, a posterior or *calcaneal* pillar and an

Fig. 252.—The Secondary Ossific Centres of the Foot.



anterior or *metatarsal* pillar. It is convenient, however, to regard the anterior part of the arch as consisting of two segments, corresponding to the medial and lateral borders of the foot respectively. The medial segment is made up of the three metatarsal bones, the three cuneiform, the navicular, and talus; the lateral segment is made up of the fourth and fifth metatarsal bones, the cuboid, and the calcaneus, and both segments are supported behind on a common *calcaneal* pillar. The division corresponds to a difference in function of the two longitudinal arches. Both are intimately concerned in ordinary locomotion. In addition, the medial, characterised by its great curvature and remarkable elasticity, sustains the more violent concussions in jumping and similar actions, whereas the lateral, less curved, more rigid, and less elastic arch forms, with the pillars in front and behind, a firm basis of support in the upright posture.

Both arches are completed and maintained by strong ligaments and tendons. The weakest part is the joint between the talus and navicular bone, and special

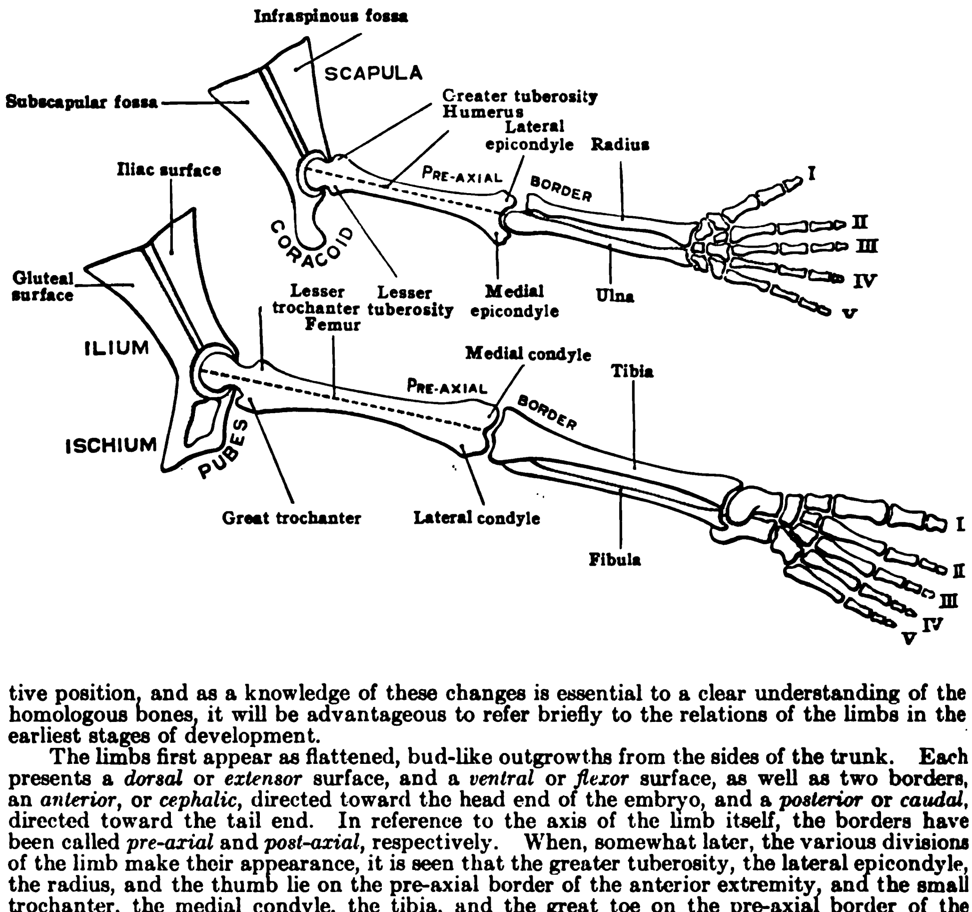
provision is accordingly made, by the addition of a strong calcaneo-navicular ligament, for the support of the head of the talus. This ligament is in turn supported by its union with the deltoid ligament of the ankle, and by the tendon of the *tibialis posterior* which passes beneath it to its insertion.

Besides being arched longitudinally, the foot presents a transverse arch formed by the metatarsal bones in front and the distal row of the tarsus behind. It is produced by the marked elevation of the central portion of the medial longitudinal arch above the ground, whereas the lateral longitudinal arch is much less raised, and at its anterior end becomes almost horizontal. Both the longitudinal and transverse arches serve the double purpose of increasing the strength and elasticity of the foot and of providing a hollow in which the muscles, nerves, and vessels of the sole may lie protected from pressure.

Homology of the Bones of the Limbs

That there is a general correspondence in the plan of construction of the two extremities is apparent to a superficial observer, and this becomes more marked when a detailed examination of the individual bones, their forms and relations, their embryonic and adult peculiarities, is systematically carried out. In each limb there are four segments, the shoulder girdle corresponding to the pelvic girdle, the arm to the thigh, the forearm to the leg, and the hand to the foot. These parts have been variously modified, in adaptation to the different functions of the two limbs, particularly as regards the deviations or changes from what is regarded as their primi-

Fig. 253.—Diagrammatic Representation of the Bones of the Two Limbs, to show Homologous Parts. (Modified from Flower.)



tive position, and as a knowledge of these changes is essential to a clear understanding of the homologous bones, it will be advantageous to refer briefly to the relations of the limbs in the earliest stages of development.

The limbs first appear as flattened, bud-like outgrowths from the sides of the trunk. Each presents a *dorsal* or *extensor* surface, and a *ventral* or *flexor* surface, as well as two borders, an *anterior*, or *cephalic*, directed toward the head end of the embryo, and a *posterior* or *caudal*, directed toward the tail end. In reference to the axis of the limb itself, the borders have been called *pre-axial* and *post-axial*, respectively. When, somewhat later, the various divisions of the limb make their appearance, it is seen that the greater tuberosity, the lateral epicondyle, the radius, and the thumb lie on the pre-axial border of the anterior extremity, and the small trochanter, the medial condyle, the tibia, and the great toe on the pre-axial border of the posterior extremity. Further on the post-axial border of the anterior extremity are seen the lesser tuberosity, the medial epicondyle, the ulna, and little finger, whilst on the corresponding border of the posterior limb are the great trochanter, the lateral condyle, the fibula, and the little toe. The parts now enumerated on the corresponding borders of the two limbs must therefore be regarded as serially homologous (fig. 253).

It is necessary to trace next the further changes which take place in the segments of the limbs up to the time when they assume their permanent positions. They may be arranged in stages as follows:—

(1) Each segment of the limb is bent upon the one above it. The humerus and femur remain unchanged. The forearm segment, however, is bent so that the ventral surface looks medially and the dorsal surface laterally. Moreover, the joints between these segments—i. e., elbow and knee—form marked projections. The terminal segments (hand and foot) are bent in the opposite direction to the middle one, so that the primitive position is retained, and the ends of the digits directed laterally. It will be noticed that in this series of changes the relations of the pre-axial and post-axial borders of the limbs remain as before.

(2) This stage consists in a rotation of the whole limb from the proximal end, though in an exactly opposite direction in each case. The anterior extremity is rotated *backward* so that the humerus lies parallel with the trunk; the elbow is directed toward the caudal end, the pre-axial (radial) border becomes lateral, and the post-axial border medial. The ends of the digits point backward. The posterior extremity undergoes a rotation *forward* to the same extent, so that the femur is also nearly parallel with the trunk; the knee is directed toward the head end, the pre-axial (tibial) border becomes medial, and the post-axial border lateral. The tibia and fibula are parallel, the ends of the digits are directed forward, the great toe is on the pre-axial and the little toe on the post-axial border of the limb, and in this position the posterior extremity remains, the changes being finally completed by the extension of the limb at the hip-joint as the body attains its full development.

(3) This stage affects the anterior extremity alone and consists in a rotation of the radius, carrying the hand round the ulna so that the digits are brought round from the back to the front of the limb, and in many animals the manus is thus placed permanently in the prone position. But in man, in whom the capacity for pronation and supination is highly developed, the hand can assume either position at will. In his case the final change is the extension which takes place at the shoulder-joint with the assumption of the upright posture, the limb dropping loosely at the side of the body, and being endowed with the greatest freedom of movement.

Homological comparison of—

I. The shoulder and pelvic girdles.—Primarily the lateral half of each girdle consists of a curved bar or rod of cartilage placed at right angles to the longitudinal axis of the trunk and divisible into a dorsal segment, and a ventral segment, the point of division corresponding to the place of articulation with the limb-stalk—i. e., the glenoid and acetabular cavities. In the fore-limb the dorsal segment is the scapula, and the ventral segment the coracoid, whilst in the hind-limb the dorsal segment is the ilium and the ventral segment the ischium and pubis.

The dorsal segments of the two girdles—i. e., scapula and ilium—are accordingly regarded as homologous bones, the chief difference being that whereas the scapula is free from articulation with the vertebral column, the ilium is firmly jointed to the rib elements (lateral mass) of the sacrum. But the correspondence is not quite so clear with regard to the ventral segments. In the primitive condition the coracoid articulates with the side of the sternum, an arrangement which persists throughout life in certain animals, such as reptiles and Ornithorhynchus. But in all the higher mammals it undergoes reduction, withdrawing from the side of the sternum, and eventually forming a more or less rudimentary process attached to the scapula. In the more generalised form of shoulder girdle the ventral bar is double, consisting of coracoid and pre-coracoid elements, the latter being situated in front and almost parallel with the coracoid. The pre-coracoid in mammals is largely replaced by the development over it of the clavicle, a dermal or membranous splint-bone which eventually invades the underlying cartilage. Parts, however, remain distinct and form the sternal epiphysis of the clavicle, the inter-articular cartilage between it and the sternum, the supra-sternal bones, and the inconstant inter-articular cartilage in the acromio-clavicular joint.

It has already been noticed that in the hip girdle the ventral segment also consists of two elements, the pubis and ischium. Both take part in the formation of the acetabular cavity, and the pubis meets in the ventral median line the corresponding segment of the opposite side.

It is generally agreed that the coracoid and ischium are homologous structures. The pubic portion of the ventral segment appears to correspond most closely with the pre-coracoid element of reptiles, so that there is no true homologue of the clavicle in the pelvis. If, however, the clavicle corresponds to the reptilian pre-coracoid, as believed by many anatomists, it then becomes the representative of the pubis.

From a consideration of the condition in cranio-cleido-dysostosis, Mr. Fitzwilliams has put forward the following views regarding the homology of the shoulder girdle:—Coracoid bar is represented by (a) medial two-thirds of clavicle; (b) coraco-clavicular ligaments; and (c) sub-coracoid centre of coracoid process. The clavicula, a membranous bone, is represented by the lateral third of adult clavicle. The pre-coracoid bar is represented by:—(a) the coracoid process (less the sub-coracoid centre); and (b) the costo-coracoid ligament. The epi-coracoid is represented by the meniscus of the sterno-clavicular joint.

Moreover, it is possible to establish a comparison between the individual parts of the ilium and scapula. A reference to fig. 253 shows that both the scapula and ilium may be resolved into three-sided prismatic rods, each of which has three surfaces and three borders. In the primitive position of the limb one surface—the *internal*—is turned toward the vertebral column, the remaining surfaces are *external*, and named *pre-axial* and *post-axial*, corresponding to the borders of the limb. The borders separating the internal from the external surfaces are antero-internal (terminating in the acromion or pubis) and postero-internal (terminating in the coracoid or ischium). The two external surfaces are separated by a ridge, terminating below at the upper margin of the glenoid cavity or acetabulum (glenoid and cotyloid borders).

The primitive arrangement is lost by the marked growth of the borders of the rods leading to the formation of fossæ and by the rotation of each rod, the scapula *laterally* and the ilium *medially*, in association with the rotation which takes place in the free part of the limb, so that

the inner surface of the one comes to correspond with the outer surface of the other. It results that the primitive vertebral surface of the scapula is now the pre-scapular or supraspinous fossa, and the corresponding surface in the ilium is the sacral, which, on account of its close connection with the vertebral column, undergoes but little change in position. Further, the primitive pre-axial surfaces are the infraspinous fossa and the iliac fossa, which accordingly are to be regarded as homologous, as well as the two post-axial surfaces, the subscapular fossa and the dorsum ilii. The correspondence between the various parts of the scapula and ilium is shown in the appended table (after Flower).

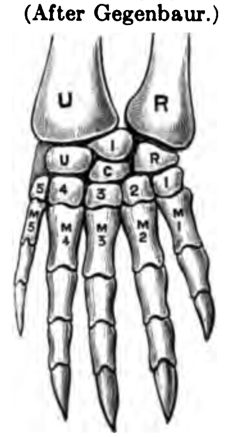
	Scapula	Primitive Arrangement	Ilium
I. **Surfaces:**	Supraspinous fossa.	Vertebral.	Sacral surface.
	Infraspinous fossa.	Pre-axial.	Iliac fossa.
	Subscapular fossa.	Post-axial.	Gluteal surface.
II. **Borders:**	Axillary or glenoid.	External.	Cotyloid or anterior border.
	Spine.	Antero-internal.	Terminal line.
	Superior or coracoid.	Postero-internal.	Posterior border.
	Base.	Dorsal extremity.	Crest of ilium.

II. Bones of the arm and thigh, forearm, and leg.—It has already been pointed out in describing the deviation of the limbs from the primitive position that the humerus corresponds to the femur, the radius to the tibia, and the ulna to the fibula; also that in consequence of the rotation backward of the fore-limb, and forward of the hind-limb, the lateral side of the humerus corresponds with the medial side of the femur, the radial border of the forearm to the tibial border of the leg, and the ulnar (border of the forearm) to the fibular border of the leg. The corresponding parts are tabulated below:—

Fore-Limb	Hind-Limb
Humerus	Femur
Greater tuberosity	Lesser Trochanter
Lesser tuberosity	Great Trochanter
Lateral epicondyle and capitulum	Medial Condyle
Medial epicondyle and trochlea	Lateral Condyle
Radius	Tibia
Ulna	Fibula
Not represented	Patella

III. Bones of the hand and foot.—It is obvious that the carpus and tarsus, the metacarpus and metatarsus, and the various digits, commencing at the thumb, in the hand, and at the great toe, in the foot, are serially homologous.

FIG. 254.—DORSAL SURFACE OF THE RIGHT MANUS OF A WATER-TORTOISE, *Chelydra serpentina.* (After Gegenbaur.)



In order to trace the correspondence between the various elements of the carpus and tarsus it is convenient to refer in the first place to the primitive type of hand and foot as found in the water-tortoise and the lizard (fig. 254). In each segment nine elements may be recognised, arranged in a proximal row of three, named respectively *radiale* or *tibiale*, *intermedium*, and *ulnare*, or *fibulare*, a distal row of five *carpalia*, or *tarsalia*, numbered from one to five, commencing at the pre-axial border, and between the two rows an *os centrale*.

In man the carpus is derived from the typical form in the following manner: The radiale forms the navicular, intermedium the lunate, and the ulnare, the triquetral; carpale I forms the greater multangular, carpale II the lesser multangular, carpale III the capitate, whilst carpalia IV and V coalesce to form the hamate. The os centrale is present in the human carpus at an early stage, but in the second month it joins the navicular. It is occasionally separate—a normal arrangement in most of the primates.

In the tarsus, the tibiale and intermedium coalesce to form the talus, and the fibulare becomes the calcaneus. It is interesting to note that although in the human subject there are three bones in the first row of the carpus and two in the first row of the tarsus, in carnivores the navicular and lunate are united to form a naviculo-lunate bone—the homologue of the talus. In the human tarsus the intermedium occasionally remains distinct as the *os trigonum*.

Tarsale I forms the first cuneiform, tarsale II the second cuneiform, tarsale III the third cuneiform, and tarsale IV and V are joined to form the cuboid. The os centrale forms the navicular.

In addition to the carpal and tarsal elements enumerated above, brief mention must now be made of the sesamoid bones of the two segments, which are regarded by many anatomists as vestiges of suppressed digits. In the hand are the **ulnar** and **radial sesamoids**, the ulnar being represented by the pisiform and the radial probably by the tuberosity of the navicular. (In the mole and other allied species with fossorial habits, the radial sesamoid is greatly developed to form a sickle-shaped bone which has received the name of *os falciforme*.)

The corresponding structures in the foot are the **tibial** and **fibular sesamoids**, the tibial being most nearly represented by the tuberosity of the navicular and the fibular by the tuber of the calcaneus.

TABLE SHOWING THE HOMOLOGOUS BONES OF THE CARPUS AND TARSUS. (*After G. D. Thane in Quain's Anatomy.*)

CARPUS	PRIMITIVE NAMES		TARSUS
Triquetral	Ulnare	Fibulare	Calcaneus
Pisiform	Ulnar sesamoid	Fibular sesamoid	
Lunate	Intermedium	Intermedium	Talus
Navicular	Radiale	Tibiale	
	Radial sesamoid	Tibial sesamoid	Navicular
	Centrale	Centrale	
Greater multangular	Carpale I	Tarsale I	First cuneiform
Lesser multangular	" II	" II	Second cuneiform
Capitate	" III	" III	Third cuneiform
Hamate	" IV	" IV	Cuboid
	" V	" V	

References.—For the *development* of the skeleton, consult the bibliography in Bardeen's article in Keibel and Mall's 'Human Embryology,' Vol. 1. For further references concerning the *adult structure* and *morphology* of the skeleton, the sections on osteology in the larger works on human anatomy by Quain, von Bardeleben, Rauber-Kopsch. Poirier-Charpy, etc., should be consulted. References to the most recent literature may be found in Schwalbe's Jahresbericht, the Index Medicus, and in the various anatomical journals.

SECTION III

THE ARTICULATIONS

REVISED FOR THE FIFTH EDITION

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THE CONSTITUENTS OF AN ARTICULATION

THE section devoted to the Articulations or Joints deals with the union of the various and dissimilar parts of the human skeleton. The following structures enter into the formation of joints.

Bones constitute the basis of most joints. The long bones articulate by their ends, the flat by their edges, and the short at various parts on their surfaces. The articular ends are usually expanded, and are composed of cancellous tissue, surrounded by a dense and strong shell of compact tissue.

This shell has no Haversian canals (the vessels of the cancellous tissue turn back and do not perforate it), or large lacunæ, and no canaliculi, and is thus well adapted to bear pressure. This "osteoid" layer may represent in part calcified cartilage rather than true bone.

The **cartilage** which covers the articular ends of the bones is called **articular,** and is of the **hyaline variety.** It is firmly implanted on the bone by one surface, while the other is smooth, polished, and free, thus reducing friction to a minimum, while its slight elasticity tends to break jars. It ends abruptly at the edge of the articulation, and is thickest over the areas of greatest pressure.

Another form of cartilage, the white fibrous, is also found in joints:—

(i) As *interarticular cartilage* in diarthrodial joints—viz., in the knee, mandibular, sterno-clavicular, radio-carpal, and occasionally in the acromio-clavicular joint. It is interposed between the ends of the bones, partially or completely dividing the synovial cavity into two. It serves to adjust dissimilar bony surfaces, adding to the security of, while it increases the extent of motion at, the joint; it also acts as a buffer to break shocks.

(ii) As *circumferential* or marginal fibro-cartilages, which serve to deepen the sockets for the reception of the heads of bones—e. g., the glenoid ligaments of the shoulder and hip. Another form of marginal plate is seen in the accessory volar ligaments of the fingers and toes, which deepen the articulations of the phalanges and add to their security.

(iii) As *connecting fibro-cartilage.* The more pliant and elastic is the more cellular form, and is found in the intervertebral discs; while the less yielding and more fibrous form is seen in the sacro-iliac and pubic articulations, where there is little or no movement.

The **ligaments** which bind the bones together are strong bands of white fibrous tissue, forming a more or less perfect capsule [capsula articularis], round the articulation. They are pliant but inextensile, varying in shape, strength, and thickness according to the kind of articulation into which they enter. They are closely connected with the periosteum of the bones they unite. In some cases—as the ligamenta flava which unite parts not in contact—they are formed of yellow elastic tissue.

The **synovial membrane** [stratum synoviale] lines the interior of the fibrous ligaments, thus excluding them, as well as the cushions or pads of fatty tissue situate within and the tendons which perforate the fibrous capsule, from the articular cavity. It is a thin, delicate membrane, frequently forming folds and fringes which project into the cavity of the joint; or, as in the knee, stretches across the cavity, forming a so-called synovial ligament. In these folds are often found pads of fatty tissue, which fill up interstices, and form soft cushions between the contiguous bones. The amount of fat that is normally present within a joint varies greatly. It is an old observation that although there is always fat in the hip-

and knee-joints, there is usually none within the shoulder-joint. Sometimes these fringes become villous and pedunculated, and cause pain on movement of the joints. They contain fibro-fatty tissue, with an isolated cartilage cell or two. The synovial membrane is well supplied with blood, especially near the margins of the articular cartilages and in the fringes. It secretes a thick, glairy fluid like white of egg, called synovia, which lubricates the joint. Another variety of synovial membrane is seen in the bursæ, which are interposed between various moving surfaces. In some instances bursæ in the neighbourhood of a joint may communicate with the synovial cavity of that joint.

CLASSIFICATION OF ARTICULATIONS

Joints may be classified:—(*a*) From an anatomical point of view, with regard to the substances and the arrangement of the substances by which the constituent parts are united. (*b*) From a physiological standpoint, with regard to the greater or smaller mobility at the seat of union. (*c*) From a physical standpoint, either the shapes of the portions in contact being mainly considered or the axes round which movement can occur. Or again (*d*) a combination of the preceding methods may be adopted, and this is the plan most generally followed. None of the classifications hitherto used is quite satisfactory, but perhaps, on the whole, that suggested by Prof. Alex. Macalister is the least open to objection, and therefore with slight modification it is utilised here.

There are three chief groups of joints:—

1. *Synarthroses.* In joints of this class the bones are united by fibrous tissue.
2. *Synchondroses.* Or joints in which the uniting substance intervening between the bones is cartilage.
3. *Diarthroses.* The constituent parts of joints of this class are (*a*) two or more bones each covered by articular hyaline cartilage; (*b*) a fibrous capsule uniting the bones, and (*c*) a synovial membrane which lines the fibrous capsule and covers any part of bone enclosed in the capsule and not covered with articular cartilage. An interarticular plate of cartilage may or may not be present.

Synarthroses.—

(*a*) *Sutures* or immovable joints, in which the fibrous tissue between the bones is too small in amount to allow movement.
- (1) *Harmonic.* The edges of the bones are comparatively smooth and are in even apposition, e. g., vertical plate of palate and maxilla.
- (2) *Squamous.* The margin of one bone overlaps the other, e. g., temporal and parietal.
- (3) *Serrate.* The opposed edges interlock by processes tapering to a point.
- (4) *Dentate.* The opposed edges are dovetailed, e. g., occipital and parietal.
- (5) *Limbous.* The opposed edges alternately overlap, e. g., parietal and frontal.
- (6) *Schindylesis.* A ridge or flattened process is received into a corresponding socket, e. g., rostrum of sphenoid and vomer.
- (7) *Gomphosis.* A peg-like process is lodged in a corresponding socket, e. g., the fangs of the teeth.

(*b*) *Syndesmoses.* Movable joints in which the fibrous tissue between bones or cartilages is sufficiently lax to allow movement between the connected parts, e. g., thyreo-hyoid membrane. Interosseous membranes of forearm and leg.

2. **Synchondroses.**—In all synchondroses a certain amount of movement is possible, and they are often called amphiarthroses.
- (1) *True synchondroses.* The cartilage connecting the bones is the remains of the bar in which the bones were ossified, e. g., occipito-sphenoidal joint.
- (2) *False synchondroses.* The plate of cartilage intervening between and connecting the bones is fibro-cartilage and is not part of the cartilage in which the bones were ossified, but is developed separately, e. g., intervertebral joint and pubic symphysis. The articular end of each bone may be covered with hyaline cartilage and there may be a more or less well-marked cavity in the intervening plate of fibro-cartilage.

3. **Diarthroses.**—In diarthrodial joints the surfaces in contact may be equal and similar or unequal and dissimilar. In the former case the joints are homomorphic; in the latter, heteromorphic.

(A) *Homomorphic.*
- (*a*) *Plane or arthrodial.* Flat surfaces, admitting gliding movement, e. g., intercarpal and acromio-clavicular joints.
- (*b*) *Ephippial.* Saddle-shaped surfaces placed at right angles to each other, admitting free movement in all directions, e. g., metacarpo-phalangeal joint of thumb.

(B) *Heteromorphic.*
- (*a*) *Enarthrodial.* Ball-and-socket, allowing the most free movement, e. g., hip- and shoulder-joints.
- (*b*) *Condylarthroses.* The convex surface is ellipsoidal, and fits into a corresponding concavity, e. g., wrist and metacarpo-phalangeal joints.
- (*c*) *Ginglymi.* One surface consists of two conjoined condyles or of a segment of a cone or cylinder, and the opposite surface has a reciprocal contour. In these joints movement is only permitted round one axis, which may be transverse; e. g., elbow, ankle; or it may be vertical, in which case the joint is trochoid; e. g., odontoid process of axis with atlas, radius with ulna.

Such a classification should be considered as being purely academic and the student must always remember that it is not enough to discuss a joint by assigning it to a particular class in any scheme; for he must be familiar with the actual conditions present in every joint. No classification, however perfect, must be taken as final, and each joint should be studied as a separate thing altogether apart from any general systematic arrangement.

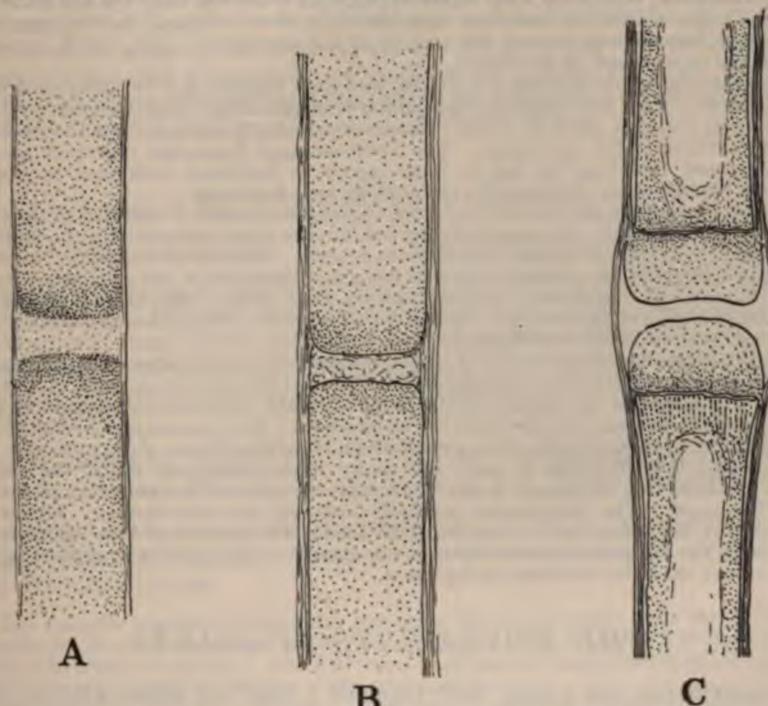
DEVELOPMENT AND MORPHOLOGY OF JOINTS

The arrangement of the various parts which constitute an articulation is best appreciated by a study of the development of the various types of joints. In this way it is easy to recognise a primitive condition typical of each class; but it must be remembered that various modifications take place during growth, that these modifications vary in the individual joints, and produce adult departures from the primitive arrangement which are peculiar to each joint and which must be studied separately.

In the case of bones ossifying in membrane the articulation will be a **suture,** the ossifications from neighbouring centres extending until they practically come into contact.

FIG. 255.—DEVELOPMENT OF JOINTS

A. Stage in which primary embryonic tissue separates the developing cartilages.
B. Primary embryonic tissue transformed into cartilage (synchondrosis), or fibrous connective tissue (syndesmosis).
C. Degeneration of embryonic tissue with production of a joint cavity (diarthrosis).



With cartilage bones the articulation may be either a syndesmosis, a synchondrosis, or a diarthrosis. The embryonic tissue in which the cartilage is to develop is at first continuous; centres of chondrification, corresponding in number to the bony elements which are destined to be formed, appearing in it. As the chondrifications approach each other a small portion of the primary embryonic tissue persists between them (fig. 255), and it is the subsequent fate of this intermediate tissue that determines the nature of the articulation.

(1) When the ossification of the cartilage occurs to form the articulating bones, the intermediate tissue may undergo transformation into cartilage (fig. 255), a **synchondrosis** being thus produced. (2) Or the intermediate tissue may be converted into fibrous connective-tissue

(fig. 255), the result being a **syndesmosis.** (3) Or, finally, the central portion of the intermediate tissue may degenerate, so that an articular cavity is produced, the peripheral portions being converted into connective tissue, forming a sleeve-like capsule surrounding the cavity, continuous at either extremity with the periosteum of the articulating bones (fig. 255). This is the articular capsule, and the connective-tissue cells arranging themselves in a layer upon its inner surface give rise to a synovial membrane. As the result of these processes a **diarthrosis** is produced, and from its mode of formation it is clear that the cavity of such an articulation is completely closed.

In a typical diarthrosis there is therefore a ligamentous capsule which entirely encloses the joint cavity, which is continuous with the periosteum of the bones entering into the articulation but which is not attached to nor reflected onto the cartilaginous ends of the bones which constitute the articulating surfaces. Such a capsule constitutes the primitive bond between the articulating bones and furnishes a complete lubricating bag in which these smooth cartilaginous ends glide over one another. This primitive capsule, however, becomes modified in most adult joints, (1) by unequal development of various parts of the capsule; and (2) by the more or less complete incorporation of other structures which are developmentally separate from the capsule. Under the first heading come specially thickened bands which may be so distinctly marked off from the rest of the capsule as to be named as separate ligaments (e. g., the temporo-mandibular ligament of the mandibular joint). Again certain thickened bands of capsule may, with alteration of joint contour, take up anatomical positions which are apparently separated from the rest of the capsule; advanced examples of this process are, in all probability, seen in the ligamentum teres of the hip-joint and the crucial ligaments of the knee. Under the second heading comes a series of ligaments derived from a great variety of sources; the most common origin being from the divorced or rearranged tendons of the muscles around the joint.

Muscles arising from, or inserted into, bones in the immediate vicinity of a joint tend to become metamorphosed into tendon near their attachments, and a comprehensive study of myology in low vertebrate forms indicates that there is associated with this tissue-change a tendency for the muscle to alter its point of attachment; hence a muscle originally inserted below a joint may eventually come to have its insertion above the joint. In the same way, a muscle arising above a joint may, as a result of altered environment, shift its origin to some point below the joint. To this change of position the term **migration of muscles** has been applied. In many instances a portion of the muscle equivalent to the distance between the original and the acquired attachment persists as a fibrous band and fulfils the function of a ligament. This is well seen in the knee-joint, where the *tibial collateral* ligament is derived from the adductor magnus, this muscle having shifted its insertion from the tibia to the femur. In the same way the *fibular collateral* ligament represents the tendon of the peroneus longus, which has migrated from the femur to the head of the fibula.

Among other ligaments derived in a similar way from muscles may be mentioned the *sacro-tuberous* ligament. This was originally the tendon of origin of the biceps femoris. (H. Morris, Med. Times and Gazette, 1877, p. 361.) The *sacro-spinous* is derived from the fibrous retrogression of portions of the coccygeus. The *sacro-coccygeal* ligaments represent the muscles which lift, depress, and wag the tail in those mammals furnished with such an appendage; indeed, these ligaments are occasionally replaced by muscle-tissue.

The *coraco-humeral* ligament is derived from the original tendon of insertion of the pectoralis minor, and not unfrequently the muscle is inserted into the lesser tuberosity of the humerus, the ligament being then replaced by the tendon of the muscle. The *coraco-clavicular, rhomboid,* and *gleno-humeral* ligaments are probably derived from modifications of the subclavius muscle.

Other anatomical structures besides muscles may, when degenerated or functionally altered, form the basis of ligaments in connection with joints. The *spheno-mandibular* ligament is the fibrous remnant of the cartilaginous mandibular bar.

The pulpy substance in the centre of each *intervertebral disc* is derived from the notochord; the *apical ligament* passing from the tip of the dens to the anterior margin of the foramen magnum is a remnant of the sheath of the notochord, and indicates its position as it passed from the vertebral column into the base of the cranium. The *transverse ligament* of the atlas (as pointed out by Professor Cleland) is a persistent and functional form of the posterior conjugal ligament uniting the rib-heads in seals and many other mammals, whilst the *interosseous ligament* of the head of a rib in man is the feeble representative of this structure in the thoracic region of the spine. The *ligamentum conjugale costarum* was described by Mayer in 1834 (Müller's Archiv für Anatomie). According to Luschka's account of this ligament it would seem as though the posterior superior fibres of the capsule of the costo-central joint represented it in man, rather than the interosseous ligament.

THE MOVEMENTS OF JOINTS

The movements which may take place at a joint are either gliding, angular, rotatory, or circumductory.

The **gliding** motion is the simplest, and is common to all diarthrodial joints; it consists of a simple sliding of the apposed surfaces of the bones upon one another, without angular or rotatory motion. It is the only kind of motion permitted in the carpal and tarsal joints, and in those between the articular processes of the vertebræ.

The **angular** motion is more elaborate, and increases or diminishes the angle between different parts. There are four varieties, viz., *flexion* and *extension*, which bend or straighten the various joints, and take place in a forward and backward direction (in a perfect hinge-joint this is the only motion permitted); and *adduction* and *abduction*, which, except in the case of the fingers and toes, signifies an approach to, or deviation from, the median plane of the body. In the

case of the hand, the line to or from which adduction and abduction are made is drawn through the middle finger, while in the foot it is through the second toe.

Rotation is the revolution of a bone about its own axis without much change of position. It is only seen in enarthrodial and trochoidal joints. The knee also permits of slight rotation in certain positions, which is a distinctive feature of this articulation.

Circumduction is the movement compounded of the four angular movements in quick succession, by which the moving bone describes a cone, the proximal end of the bone forming the apex, while the distal end describes the base of the cone. It is seen in the hip and shoulder, as well as in the carpo-metacarpal joint of the thumb, which thus approximates to the ball-and-socket joint.

In some situations where a variety of motion is required, strength, security, and celerity are obtained by the combination of two or more joints, each allowing a different class of action, as in the case of the wrist, the ankle, and the head with the spine. Many of the long muscles, which pass over two or more joints, act on all, so tending to co-ordinate their movements and enabling them to be produced with the least expenditure of power. Muscles also act as elastic ligaments to the joints; and when acting as such, are diffusers and combiners, not producers of movement; the short muscles producing movement, the long diffusing it, and thus allowing the short muscles to act on more than one joint.

Muscles are so disposed at their attachments near the joints as never to strain the ligaments by tending to pull the bones apart, but, on the contrary, they add to the security of the joint by bracing the bones firmly together during their action.

The articulations may be divided for convenience of description into those: 1. of the SKULL; 2. of the TRUNK; 3. of the UPPER LIMB; and 4. of the LOWER LIMB.

THE ARTICULATIONS OF THE SKULL

The movable articulations of the skull comprise (1) the mandibular; and (2) those between the skull and the vertebral column, namely (*a*) between the occiput and atlas; (*b*) between the atlas and epistropheus (axis); and (*c*) the ligaments which connect the occiput and epistropheus.

The union of the atlas and epistropheus is described in this section because, (1) there is often a direct communication between the synovial cavity of the transverse epistrophic and the occipito-atlantal joints; (2) the rotatory movements of the head take place around the dens (odontoid process); and (3) important ligaments from the dens pass over the atlas to the occiput.

(1) THE MANDIBULAR ARTICULATION

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

The parts entering into the formation of this joint (figs. 256, 257) are:—the anterior portion of the mandibular fossa and glenoid ridge (eminentia articularis) of the temporal bone above, and the condyle of the lower jaw below. Both are covered with articular cartilage, which extends over the front of the glenoid ridge to facilitate the play of the interarticular cartilage. The ligaments which unite the bones are:

1. Articular capsule.
2. Articular disc.
3. Spheno-mandibular.
4. Stylo-mandibular.

The **articular capsule** is often described as consisting of four portions, anterior, posterior, lateral and medial, which are, however, continuous with one another around the articulation.

1. The **anterior portion** consists of a few stray fibres connected with the anterior margin of the articular disc, and attached below to the anterior edge of the condyle, and above to the front of the articular eminence. Some fibres of insertion of the *external pterygoid* pass between them to be inserted into the margin of the articular disc.

2. The **posterior portion** is attached above, just in front of the *petro-tympanic* (*Glaserian*) fissure, and is inserted into the back of the jaw just below its neck.

3. The **lateral portion** or **temporo-mandibular** (external lateral) **ligament** (fig. 256) is the strongest part of the capsule. It is broader above, where it is attached to the lower edge of the zygoma in nearly its whole length, as well as to the tubercle at the point where the two roots of the zygoma meet. It is inclined downward and backward, to be inserted into the condyle and neck of the mandible laterally. Its fibres diminish in obliquity and strength from before backward, those coming from the tubercle being short and nearly vertical.

4. The **medial portion** (or short internal lateral ligament) (fig. 257) consists of well-defined fibres, having a broad attachment, above to the lateral side of the spine of the sphenoid and medial edge of the mandibular fossa; and below, a narrow insertion to the medial side of the neck

of the condyle. Fatty and cellular tissue separate it from the spheno-mandibular ligament which is medial to it.

The **articular disc** (fig. 258) is an oval plate of fibro-cartilage interposed between and adapted to the two articular surfaces. It is thinner at the centre than at the circumference, and is thicker behind, where it covers the thin bone at the bottom of the mandibular fossa which separates it from the dura mater, than in front, where it covers the articular eminence.

FIG. 256.—LATERAL VIEW OF THE MANDIBULAR JOINT.

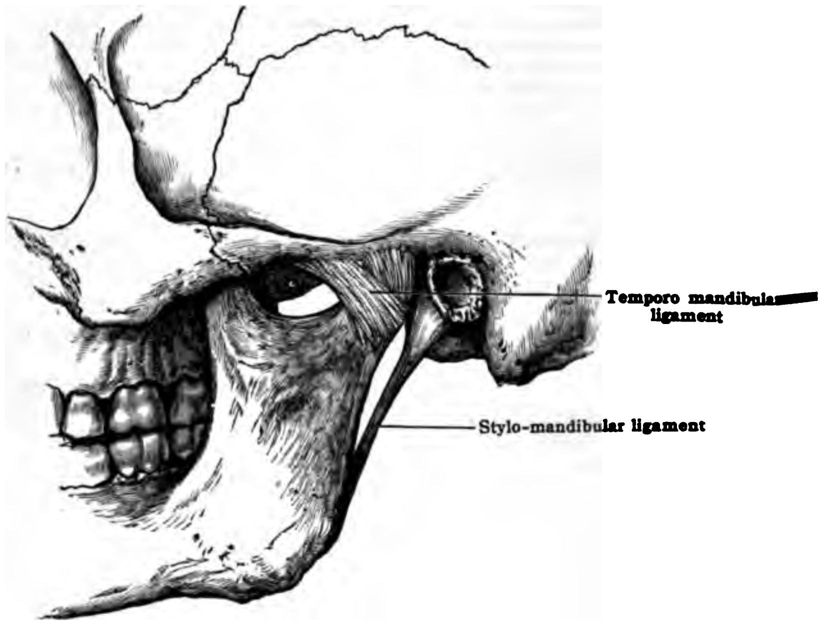
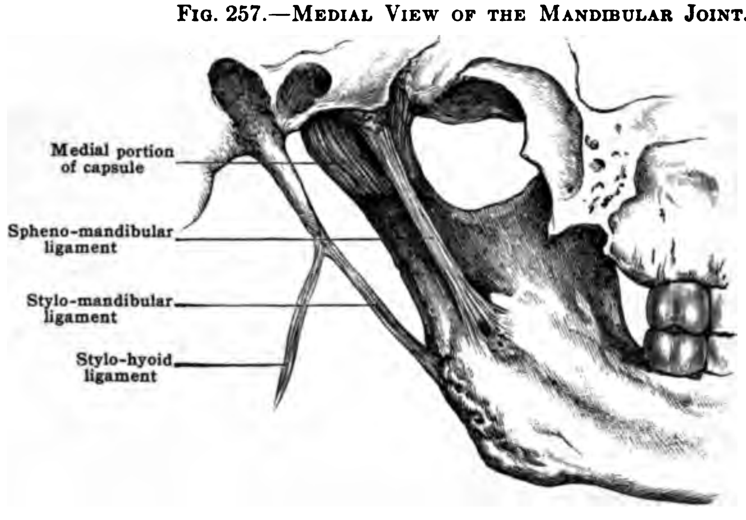


FIG. 257.—MEDIAL VIEW OF THE MANDIBULAR JOINT.



Its *inferior surface* is concave and fits on to the condyle of the lower jaw; while its *superior surface* is concavo-convex from before backward, and is in contact with the articular surface of the temporal bone. It divides the joint into two separate synovial cavities, but is occasionally perforated in the centre, and thus allows them to communicate. It is connected with the articular capsule at its circumference, and has some fibres of the *external pterygoid* muscle inserted into its anterior margin.

There are usually two **synovial membranes** (fig. 258), the superior being the larger and looser, passing down from the margin of the articular surface above, to the upper surface of the articular disc below; the lower and smaller one passes

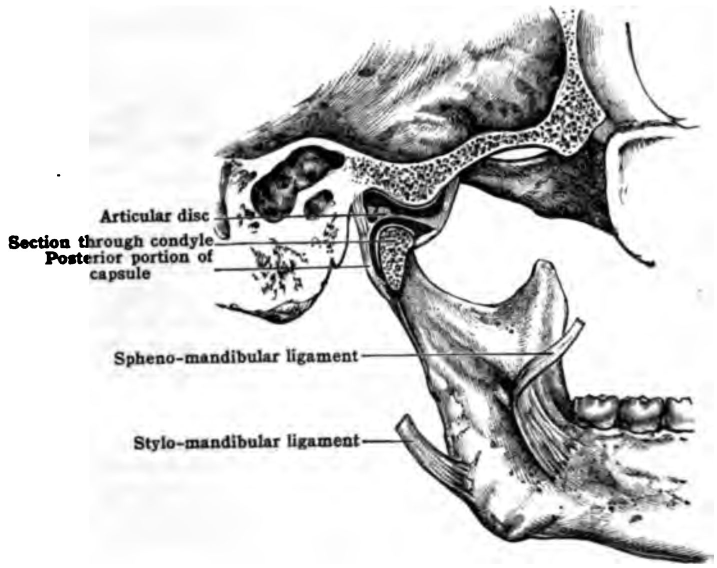
from the articular disc above to the condyle of the jaw below, extending somewhat further down behind than in front. When the disc is perforated, the two sacs communicate.

The **spheno-mandibular ligament** (long internal lateral) (fig. 257) is a thin, loose band, situated some little distance from the joint. It is attached above to the spine of the sphenoid and contiguous part of the temporal bone, and is inserted into the lingula of the lower jaw.

It covers the upper end of the mylo-hyoid groove, and is here pierced by the *mylo-hyoid* nerve. Its origin is a little medial to, and immediately behind, the origin of the medial portion of the capsule. It is separated from the joint and ramus of the jaw by the *external pterygoid* muscle, the *internal maxillary* artery and vein, the *inferior alveolar* (*dental*) nerve and artery, the *auriculo-temporal* nerve, and the *middle meningeal* artery. It is really the fibrous remnant of a part of the mandibular (Meckelian) bar.

The **stylo-mandibular ligament** (stylo-maxillary) (figs. 256 and 257) is a process of the deep cervical fascia extending from near the tip of the styloid process to the angle and posterior border of the ramus of the jaw, between the *masseter* and *internal pterygoid* muscles. It separates the parotid from the submaxillary gland, and gives origin to some fibres of the *stylo-glossus* muscle.

FIG. 258.—SAGITTAL SECTION THROUGH THE CONDYLE OF JAW TO SHOW THE TWO SYNOVIAL SACS AND THE ARTICULAR DISC.



The **arterial supply** of the mandibular joint is derived from the temporal, middle meningeal and ascending pharyngeal arteries, and from the latter by its branches to the Eustachian tube.

The **nerves** are derived from the masseteric and auriculo-temporal.

Movements.—The chief movement of this joint is of (i) a **ginglymoid or hinge character,** accompanied by a slight gliding action, as in opening or shutting the mouth. In the opening movement the condyle turns like a hinge on the articular disc, while at the same time the articular disc, together with the condyle, glides forward so as to rise upon the eminentia articularis, reaching as far as the anterior edge of the eminence, which is coated with articular cartilage to receive it; but the condyle never reaches quite so far as the summit of the eminence. Should the condyle, however, by excessive movement (as in a convulsive yawn), glide over the summit, it slips into the zygomatic fossa, the mandible is dislocated, and the posterior portion of the capsule is torn. In the shutting movement the condyle revolves back again, and the articular disc glides back, carrying the condyle with it. This combination of the hinge and gliding motions gives a tearing as well as a cutting action to the incisor teeth, without any extra muscular exertion.

There is (ii) a **horizontal gliding action** in an antero-posterior direction, by which the lower teeth are thrust forward and drawn back again: this takes place almost entirely in the upper compartment, because of the closer connection of the articular disc with the condyle than with the squamosal bone, and also because of the insertion of the *external pterygoid* into both bone and cartilage. In these two sets of movements the joints of both sides are simultaneously and similarly engaged.

The third form of movement is called (iii) the **oblique rotatory,** and is that by which the grinding and chewing actions are performed. It consists in a rotation of the condyle about

the vertical axis of its neck in the lower compartment, while the cartilage glides obliquely forward and inward on one side, and backward and inward on the other, upon the articular surface of the squamosal bones, each side acting alternately. If the symphysis be simply moved from the centre to one side and back again, and not from side to side as in grinding, the condyle of that side moves round the vertical axis of its neck, and the opposite condyle and cartilage glide forward and inward upon the mandibular fossa. But in the ordinary grinding movement, one condyle advances and the other recedes, and then the first recedes while the other advances, slight rotation taking place in each joint meanwhile.

Relations.—The chief relations are: Behind, and overlapping the lateral side, the parotid gland. Laterally, the superficial temporal artery. Medially, the internal maxillary artery and auriculo-temporal nerve. In front, the nerve to the masseter muscle.

Muscles acting on the joint.—*Elevators of the mandible.*—temporals, masseters, int. pterygoids.

Depressors.—Mylo-hyoids, digastrics, genio-hyoid, muscles connecting the hyoid bone to lower points. Ext. pterygoids. The weight of the jaw.

Protractors.—Ext. pterygoids, superficial layer of masseters, anterior fibres of temporals.

Retractors.—Posterior fibres of temporals, slightly by the int. pterygoids and deep layer of the masseters.

(2) THE LIGAMENTS AND JOINTS BETWEEN THE SKULL AND VERTEBRAL COLUMN, AND BETWEEN THE ATLAS AND EPISTROPHEUS

(a) THE ARTICULATION OF THE ATLAS WITH THE OCCIPUT

Class.—*Diarthrosis.* **Subdivision.**—*Double Condylarthrosis.*

This articulation [articulatio atlanto-occipitalis] consists of a pair of joints symmetrically situated on either side of the middle line. The parts entering into their formation are the cup-shaped superior articular processes of the atlas and the condyles of the occipital bone. They are united by the following ligaments:—

1. Anterior atlanto-occipital.
2. Posterior atlanto-occipital.
3. Two articular capsules.
4. Two anterior oblique.

The **anterior atlanto-occipital ligament** [membrana atlanto-occipitalis anterior] (fig. 259) is less than an inch (about 2 cm.) wide, and is composed of densely woven fibres, most of which radiate slightly lateralward as they ascend from the front surface and upper margin of the anterior arch of the atlas to the anterior border of the foramen magnum; it is continuous at the sides with the articular capsules, the fibres of which overlap its edges, and take an opposite direction medially and upward.

The central fibres ascend vertically from the anterior tubercle of the atlas to the pharyngeal tubercle on the occipital bone; they are thicker than the lateral fibres, and are continuous below with the superficial part of the anterior atlanto-epistrophic ligament, and through it with the anterior longitudinal ligament of the vertebral column. It is in relation, in front, with the *recti capitis anteriores;* and behind, with the apical dental or suspensory ligament.

The **posterior atlanto-occipital ligament** (fig. 260) is broader, more membranous, and not so strong as the anterior. It extends from the posterior surface and upper border of the posterior arch of the atlas to the posterior margin of the foramen magnum from condyle to condyle; being incomplete on either side for the passage of the *vertebral artery* into, and *suboccipital nerve* out of, the canal. It is somewhat thickened in the middle line by fibres, which pass from the posterior tubercle of the atlas to the lower end of the occipital crest.

It is not tightly stretched between the bones, nor does it limit their movements; it corresponds with the position of the ligamenta flava, but has no elastic tissue in its composition. It is in relation in front with the dura mater, which is firmly attached to it; and behind with the *recti capitis posteriores minores*, and enters into the floor of the suboccipital triangle. Its lateral margins, which do not reach the occipital bone but terminate on the posterior end of the superior articular processes of the atlas, form the so-called *oblique ligaments of the atlas.* The lateral margins of these ligaments are free and they form the posterior boundaries of the apertures through which the vertebral arteries enter and the suboccipital nerves leave the vertebral canal.

The **atlanto-occipital articular capsules** (figs. 259 and 260) are very distinct and strongly marked, except on the medial side, where they are thin and formed only of short membranous fibres. They are lax, and do not add much to the security of the joint.

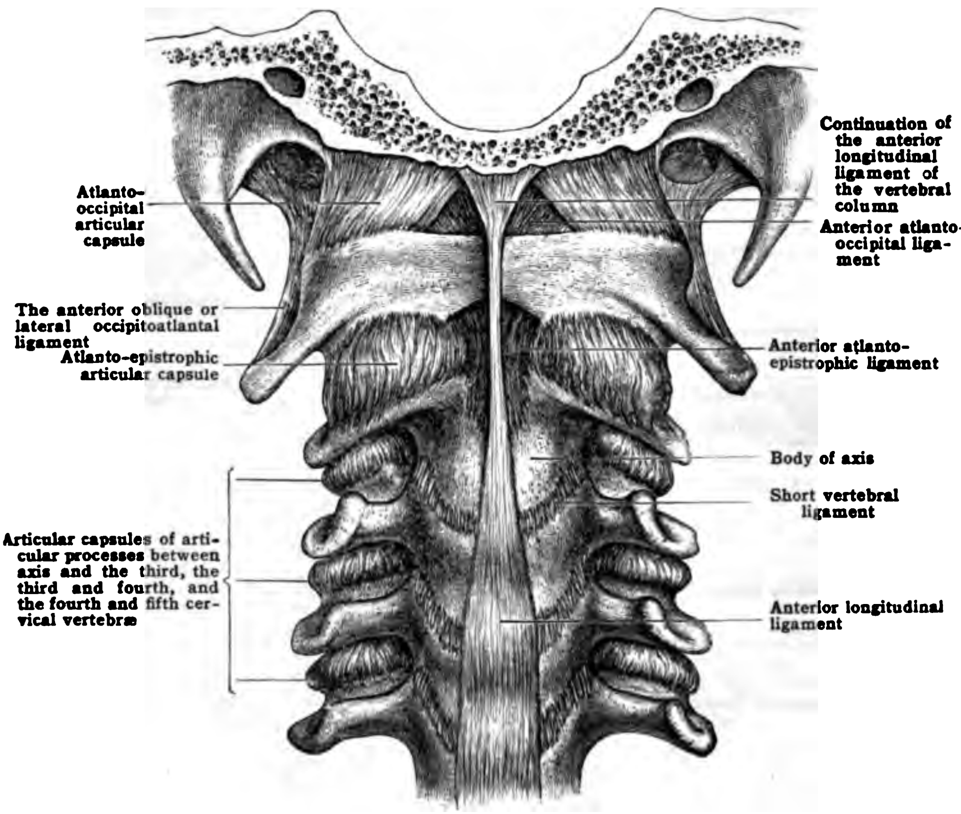
In front, the capsule descends upon the atlas, to be attached, some distance below the articular margin, to the front surface of the lateral mass and to the base of the transverse process; these fibres take an oblique course upward and medialward, overlapping the anterior atlanto-occipital. At the sides and behind, the capsule is attached above to the margins of the occipital condyles; below, it skirts the medial edge of the foramen for the vertebral artery, and behind is attached to the prominent tubercle overhanging the groove for that vessel; these latter fibres are strengthened by a band running obliquely upward and medialward to the posterior margin of the foramen magnum.

The **anterior oblique** or **lateral occipito-atlantal ligament** is an accessory band which strengthens the capsule laterally (fig. 259). It is an oblique, thick band of fibres, sometimes quite separate and distinct from the rest, passing upward and medialward from the upper surface of the transverse process beyond the costo-transverse foramen to the jugular process of the occipital bone.

The **synovial membrane** of these joints occasionally communicates with the synovial sac between the dens (odontoid process) and the transverse ligament.

The **arterial** supply is derived from twigs of the vertebral, and occasionally from twigs from the meningeal branches of the ascending pharyngeal.

FIG. 259.—ANTERIOR VIEW OF THE UPPER END OF THE VERTEBRAL COLUMN.



The **nerve-supply** comes from the anterior division of the suboccipital nerve.

Movements.—By the symmetrical and bilateral arrangement of these joints, security and strength are gained at the expense of a very small amount of actual articular surface; the basis of support and the area of action being equal to the width between the most distant borders of the joint.

The principal movement permitted at these joints is of a ginglymoid character, producing flexion and extension upon a transverse axis drawn across the condyles at their slightly constricted parts.

In flexion, the forehead and chin drop, and what is called the nodding movement is made; in extension, the chin is elevated and the forehead recedes.

There is also a slight amount of gliding movement, either **directly lateral**, the lateral edge of one condyle sinking a little within the lateral edge of the socket of the atlas, and that of the opposite condyle projecting to a corresponding degree. The head is thus tilted to one side, and it is even possible that the weight of the skull may be borne almost entirely on one joint, the articular surfaces of the other being thrown out of contact.

Or the movement may be **obliquely lateral,** when the lower side of the head will be a trifle

in advance of the elevated side. In this motion, which takes place on the antero-posterior axis, one condyle advances slightly and approaches the middle line, while the other recedes. This is of the nature of rotation, though there is no true rotation round a vertical axis possible between the occiput and atlas.

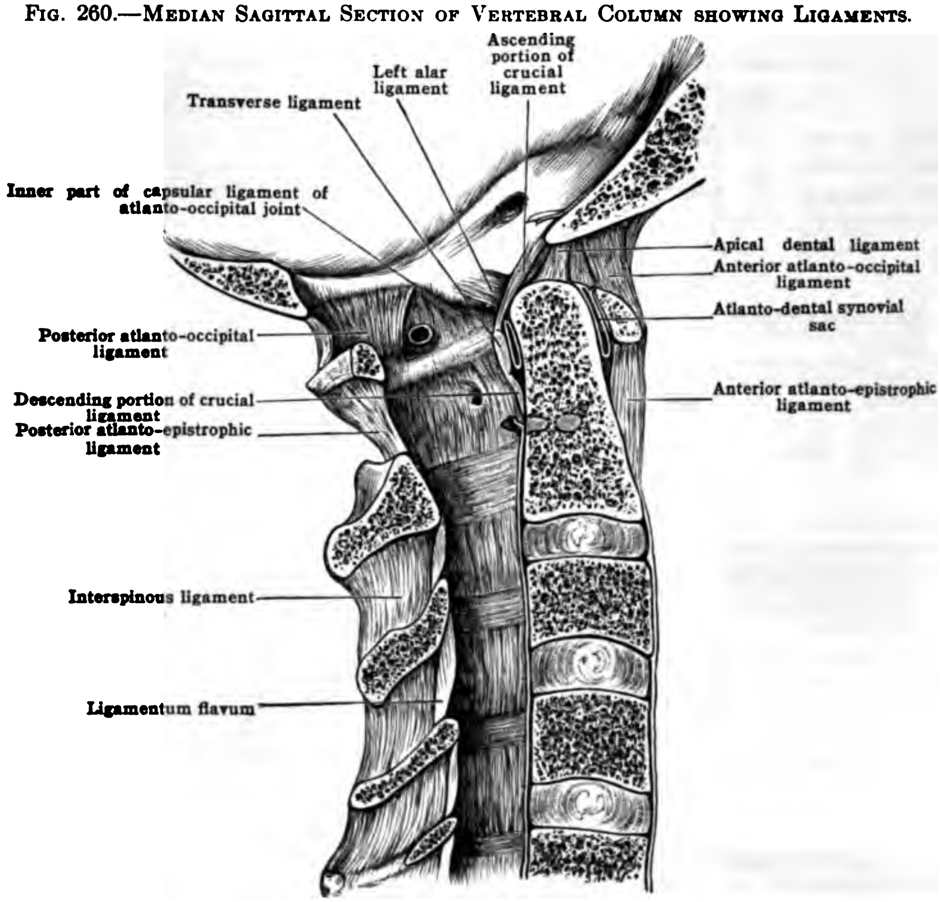
These lateral movements are checked by the alar ligaments and the lateral part of the capsules; extension is checked by the anterior atlanto-occipital and anterior oblique ligaments, and flexion by the posterior part of the capsule and the tectorial membrane.

Muscles acting upon the occipito-atlantal joint.—Flexion whereby the chin is approximated toward the sternum is produced by the weight of the anterior part of the head and by all muscles which are attached to the hyoid bone or to the bones of the skull in front of a transverse axis between the two condyles. These muscles take their fixed point below either from the vertebral column, the sternum, or the bones of the shoulder girdle. Before those connected with the mandible can act that bone must be fixed by the muscles of mastication which, therefore, also take part in the movements. It must be noted that the sterno-mastoid muscles are powerful flexors, although a part of their insertion is behind the transverse axis between the two condyles.

Extension is due to the action of muscles or portions of muscles inserted into the skull behind the transverse axis above mentioned, and connected below either with the vertebral column, shoulder girdle, or sternum.

Lateral movement is produced by the anterior and posterior groups of muscles on the same side acting simultaneously and aided by the rectus capitis lateralis of that side.

FIG. 260.—MEDIAN SAGITTAL SECTION OF VERTEBRAL COLUMN SHOWING LIGAMENTS.



(b) THE ARTICULATIONS BETWEEN THE ATLAS AND EPISTROPHEUS (AXIS).

1. THE LATERAL ATLANTO-EPISTROPHIC JOINTS.	**Class.**—*Diarthrosis.* **Subdivision.**—*Arthrodia.*
2. THE CENTRAL ATLANTO-EPISTROPHIC JOINT OR THE ATLANTO-DENTAL.	**Class.**—*Diarthrosis.* **Subdivision.**—*Trochoides.*

The bones that enter into the formation of the lateral joints are the inferior articular processes of the atlas and the superior of the epistropheus (axis); the central joint is formed by the dens (odontoid process) articulating in front with the atlas, and behind with the transverse ligament.

The ligaments which unite the epistropheus and atlas are:—

1. The anterior atlanto-epistrophic.
2. The posterior atlanto-epistrophic.
3. Two articular capsules (for lateral joints).
4. The transverse ligament.
5. The atlanto-dental articular capsule.

The **anterior atlanto-epistrophic ligament** (figs. 259 and 260) is a narrow but strong membrane filling up the interval between the lateral joints. It is attached above to the front surface and lower border of the anterior arch of the atlas, and below to the transverse ridge on the front of the body of the epistropheus. Its fibres are vertical, and are thickened in the median line by a dense band which is a continuation upward of the anterior longitudinal ligament of the vertebral column.

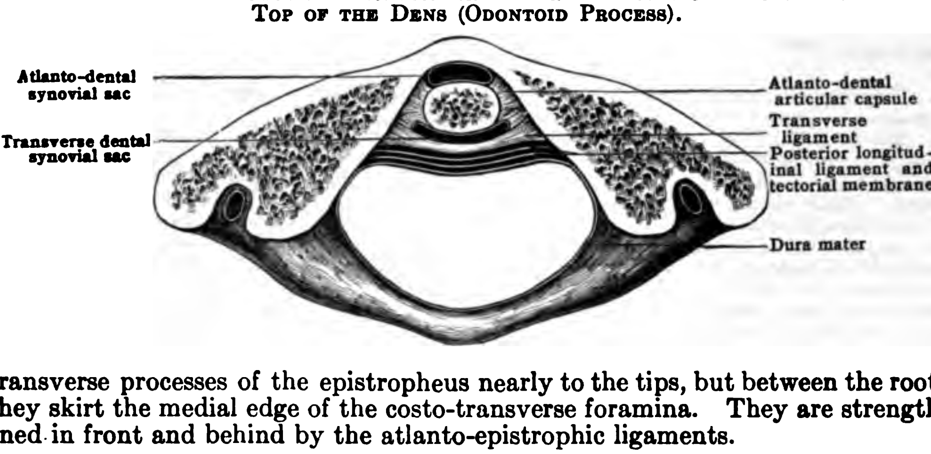
This band is fixed above to the anterior tubercle of the atlas, where it becomes continuous with the central part of the anterior atlanto-occipital ligament (fig. 259); it is sometimes separated by an interval from the deeper ligament, and is often described as the superficial atlanto-epistrophic ligament. It is in relation with the *longus colli* muscle.

The **posterior atlanto-epistrophic ligament** (fig. 260) is a deeper, but thinner and looser membrane than the anterior. It extends from the posterior root of the transverse process of one side to that of the other, projecting laterally beyond the posterior part of the capsules which are connected with it. It is attached above to the posterior surface and lower edge of the posterior arch of the atlas, and below to the superior edge of the laminæ of the epistropheus on their dorsal aspect.

It is denser and stronger in the median line, and has a layer of elastic tissue on its anterior surface like the ligamenta flava, to which it corresponds in position. It is connected in front with the dura mater; behind, it is in relation with the *inferior oblique* muscles, and is perforated at each side by the *second cervical* nerve.

1. The Lateral Atlanto-epistrophic Joints are provided with short, ligamentous fibres, forming **articular capsules** (fig. 259), which completely surround the lateral articular facets. Lateral to the canal they are attached some little distance from the articular margins, extending along the roots of the transverse processes of the epistropheus nearly to the tips, but between the roots they skirt the medial edge of the costo-transverse foramina. They are strengthened in front and behind by the atlanto-epistrophic ligaments.

Fig. 261.—Horizontal Section through the Lateral Masses of the Atlas and the Top of the Dens (Odontoid Process).



Medially each capsule is thinner, and attached close to the articular margins, being strengthened behind by a strong band of slightly oblique fibres passing upward along the lateral edge of the tectorial membrane from the body of the epistropheus to the lateral mass of the atlas behind the transverse ligament; some of these fibres pass on, thickening and blending with the atlanto-occipital capsule, to be inserted into the margin of the foramen magnum. This band is sometimes called the accessory band (fig. 263).

There is a **synovial membrane** for each joint.

2. The Central Atlanto-epistrophic Joint, although usually described as one, is composed of two articulations, which are quite separate from one another:

an anterior between the dens and the arch of the atlas, and a posterior between the dens and the transverse ligament.

The **transverse ligament** (figs. 260, 261, and 263) is one of the most important structures in the body, for on its integrity and that of the alar ligaments our lives largely depend. It is a thick and very strong band, as dense and closely woven as fibro-cartilage, about a quarter of an inch (6 mm.) deep at the sides, and somewhat more in the middle line. Attached at each end to a tubercle on the inner side of the lateral mass of the atlas, it crosses the ring of this bone in a curved manner, so as to have the concavity forward; thus dividing the ring into a smaller anterior portion for the dens and a larger posterior part for the spinal cord and its membranes, and the spinal accessory nerves.

It is flattened from before backward, being smooth in front, and covered by synovial membrane to allow it to glide freely over the posterior facet of the dens. Where it is attached to the atlas it is smooth and well rounded off to provide an easy floor of communication between the transverso-dental and occipito-atlantal joints.

To its posterior surface is added, in the middle line, a strong fasciculus of vertical fibres, passing upward from the root of the dens to the basilar border of the foramen magnum on its cranial aspect. Some of these fibres are derived from the transverse ligament. These vertical fibres give the transverse ligament a cruciform appearance; hence the name, the **crucial ligament** (figs. 260 and 263) applied to the whole.

The **atlanto-dental articular capsule** (fig. 261) is a tough, loose membrane, completely surrounding the apposed articular surfaces of the atlas and dens.

At the dens it blends above with the front of the alar and central occipito-odontoid ligaments, and arises also along the sides of the articular facet as far as the neck of the dens; the fibres are thick, and blend with the capsules of the lateral joint. At the atlas they are attached to the non-articular part of the anterior arch in front of the tubercles for the transverse ligament, blending, above and below the borders of the bone, with the anterior atlanto-occipital and atlanto-epistrophic ligaments, as well as with the medial portion of the articular capsules. It holds the dens to the anterior arch of the atlas after all the other ligaments have been divided.

The **synovial membranes** (figs. 260 and 261) are two in number:—one for the joint between the dens and atlas; and another (transverso-dental) for that between the transverse ligament and the dens. This last often communicates with the atlanto-occipital articulations; it is closed in by membranous tissue between the borders of the transverse ligament and the margin of the facet on the dens, and is separated from the front sac by the atlanto-dental articular capsule.

The arterial supply is from the vertebral artery, and the **nerve-supply** from the loop between the first and second cervical nerves.

Movements.—The chief and characteristic movement at these joints is the rotation, in a nearly horizontal plane, of the collar formed by the atlas and transverse ligament, round the dens as a pivot, which is extensive enough to allow of an all-round view without twisting the trunk. Partly on account of its ligamentous attachments, and partly on account of the shape of the articular surfaces, the cranium must be carried with the atlas in these movements. The rotation is checked by the ligaments passing from the dens to the occiput (alar ligaments), and also by the atlanto-epistrophic. Owing to the fact that the facets of both atlas and epistropheus, which enter into the formation of the lateral atlanto-epistrophic articulations, are convex from before backward, and have the articular cartilage thicker in the centre than at the circumference, the motion is not quite horizontal but slightly curvilinear. In the erect position, with the face looking directly forward, the most convex portions of the articular surfaces are alone in contact, there being a considerable interval between the edges; during rotation, therefore, the prominent portions of the condyles of the atlas descend upon those of the epistropheus, diminishing the space between the bones, slackening the ligaments, and thus increasing the amount of rotation, without sacrificing the security of the joint in the central position.

Besides rotation, forward and backward movements and some lateral flexion are permitted between the atlas and epistropheus, even to a greater extent than in most of the other vertebral joints.

The muscles acting upon the atlanto-epistrophic joints.—The muscles capable of producing rotation at the atlanto-epistrophic joints are those which take origin from near the mesial plane either in front or behind and which are attached above either to the atlas or the skull, lateral to the atlanto-epistrophic joints. When the muscles which lie at the back of the joint on one side act they will turn the head to the same side and will be aided by the muscles in front on the opposite side. If the muscles in front and behind on the same side act simultaneously, they will pull down the head to that side and will be aided by muscles which pass more or less vertically from the transverse process of the atlas to points below.

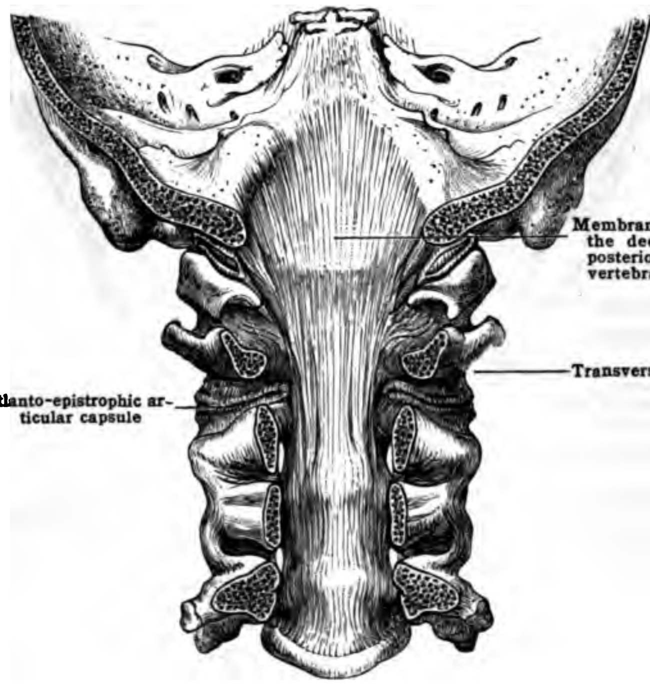
(c) The Ligaments uniting the Occiput and Epistropheus

The following ligaments unite bones not in contact, and are to be seen from the interior of the canal after removing the posterior arches of the epistropheus and atlas and posterior ring of the foramen magnum:—

1. The tectorial membrane.
2. The crucial ligament.
3. Two alar (or check) ligaments.
4. The apical dental ligament.

The **tectorial membrane** (occipito-cervical ligament) (figs. 261, 262, and 263) consists of a very strong band of fibres, connected below to the upper part of the body of the third vertebra and lower part of the body of the epistropheus as far as the root of the dens. It is narrow below, but widens out as it ascends, to be fastened to the basilar groove of the occiput. Laterally, it is connected with the accessory fibres of the atlanto-epistrophic capsule. It is really only the upward prolongation of the deep stratum of the posterior longitudinal ligament, the superficial fibres of which run on to the occipital bone without touching the epistropheus, thus giving rise to two strata. It is in relation in front with the crucial ligament.

Fig. 262.—The Superficial Layer of the Posterior Longitudinal Vertebral Ligament has been Removed to show its Deep or Short Fibres. These Deep Fibres form the Tectorial Membrane. Viewed from behind.



The **crucial ligament** has been already described (see p. 222).

The **alar** (or check) **ligaments** (figs. 260 and 263) are two strong rounded cords, which extend from the sides of the apex of the dens, transversely lateralward to the medial edge of the anterior portion of the occipital condyles.

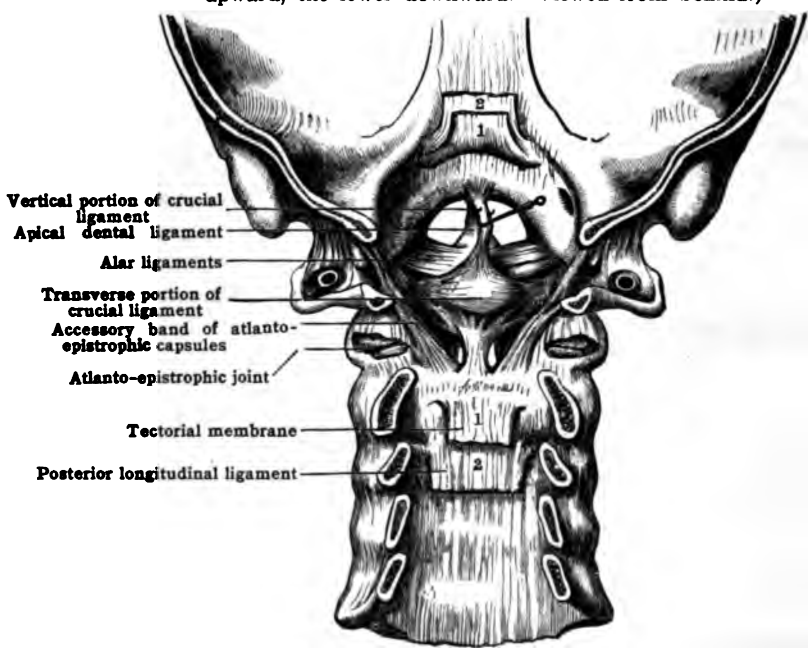
They are to be seen immediately above the upper border of the transverse ligament, which they cross obliquely owing to its forward curve at its attachments to the atlas. Some of their fibres occasionally run across the middle line from one alar ligament to the other. At the dens they are connected with the atlanto-dental capsule, and at the condyles they strengthen the atlanto-occipital articular capsule.

The **apical dental** or suspensory ligament (figs. 260 and 263) consists of a slender band of fibres ascending from the summit of the dens to the lower surface of the occipital bone, close to the foramen magnum. It is best seen from the front, after removing the anterior atlanto-occipital ligament, or from behind by drawing aside the crucial ligament.

The apical ligament is tightened by extension and relaxed by flexion or nodding; the alar ligaments not only limit the rotatory movements of the head and atlas upon the epistropheus, but by binding the occiput to the pivot, round which rotation occurs, they steady the head and prevent its undue lateral inclination upon the vertebral column. (See TRANSVERSE LIGAMENT, p. 222.)

By experiments, it has been proved that the head, when placed so that the orbits look a little upward, is poised upon the occipital condyles in a line drawn a little in front of their middle; the amount of elevation varies slightly in different cases, but the balance is always to be obtained in the human body—it is one of the characteristics of the human figure. It serves to maintain the head erect without undue muscular effort, or a strong ligamentum nuchæ and prominent dorsal spines such as are seen in the lower animals. Disturb this balance, and let the muscles cease to act, the head will either drop forward or backward according as the centre of gravity is in front or behind the balance line. The ligaments which pass over the dens to the occiput are not quite tight when the head is erect, and only become so when the head is flexed; if this were not so, no flexion would be allowed; thus, muscular action, and not ligamentous tension, is employed to steady the head in the erect position. It is through the combination of the joints of the atlas and epistropheus, and occiput and epistropheus (consisting of two pairs of joints placed symmetrically on either side of the median line, while through the median line there passes a pivot, also with a pair of joints), that the head enjoys such freedom and celerity of action, remarkable strength, and almost absolute security against violence, which could only be obtained by a ball-and socket joint; but the ordinary ball-and-socket joints are too prone to dislocations by even moderate twists to be reliable enough when the life of the individual depends on the perfection of the articulation: hence the importance of this combination of joints.

FIG. 263.—CORONAL SECTION OF THE VERTEBRAL COLUMN AND THE OCCIPITAL BONE TO SHOW LIGAMENTS.
(The tectorial membrane (1), though shown as a distinct stratum, is really the deeper part of the posterior longitudinal ligament (2). The upper ends have been reflected upward, the lower downward. Viewed from behind.)



THE ARTICULATIONS OF THE TRUNK

These may be divided into the following sets:—

1. Those of the vertebral column. Joints and ligaments connecting:
   - (a) The bodies.
   - (b) The articular processes.
   - (c) The laminæ.
   - (d) The spinous processes.
   - (e) The transverse processes.
2. Vertebral column with the pelvis.
3. Pelvis.
   - (a) Sacro-iliac
   - (b) Sacro-coccygeal.
   - (c) Intercoccygeal.
   - (d) Symphysis pubis.

4. Ribs with the vertebral column.
5. The articulations at the front of the thorax.
   (a) Costal cartilages with the sternum.
   (b) Costal cartilages with the ribs.
   (c) Sternal.
   (d) Certain costal cartilages with each other.

1. THE ARTICULATIONS OF THE VERTEBRAL COLUMN

There are two distinct sets of articulations in the vertebral column:—

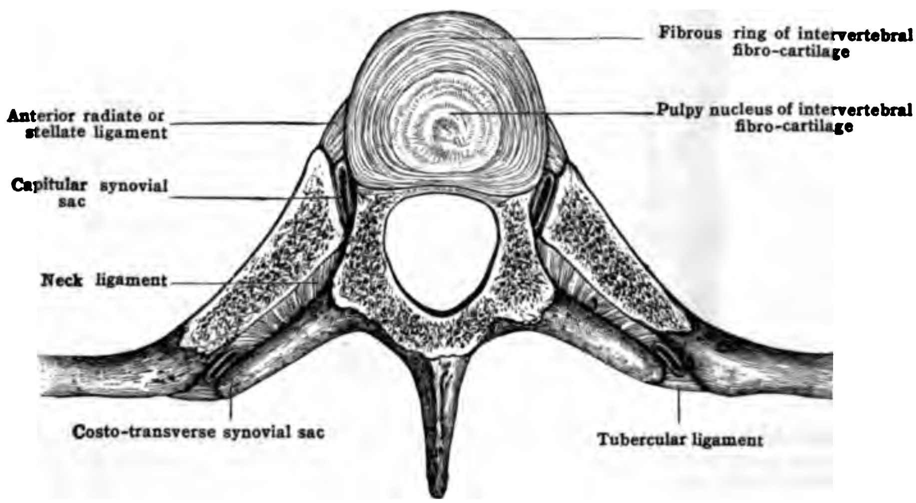
(a) Those between the bodies and intervertebral discs which form synchondroses and which are amphiarthrodial as regards movement.
(b) Those between the articular processes which form arthrodial joints.

The ligaments which unite the various parts may also be divided into two sets, viz.—**immediate,** or those that bind together parts which are in contact; and **intermediate,** or those that bind together parts which are not in contact.

Immediate.
(a) Those between the bodies and discs.
(b) Those between the articular processes.

Intermediate.
(c) Those between the laminæ.
(d) Those between the spinous processes.
(e) Those between the transverse processes.

FIG. 264.—HORIZONTAL SECTION THROUGH AN INTERVERTEBRAL FIBRO-CARTILAGE AND THE CORRESPONDING RIBS.



(a) THE ARTICULATIONS OF THE BODIES OF THE VERTEBRÆ

Class.—*False Synchondrosis.*

The ligaments which unite the bodies of the vertebræ are:—

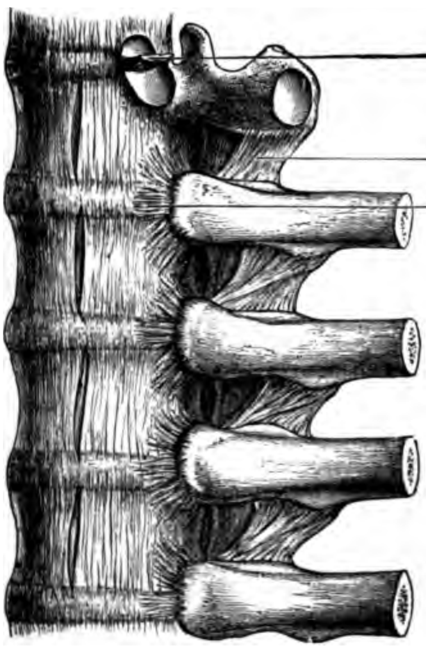
Intervertebral fibro-cartilages.	Anterior longitudinal.
Short lateral ligaments.	Posterior longitudinal.

The **intervertebral fibro-cartilages** (figs. 260 and 264) are tough, but elastic and compressible discs of composite structure, which serve as the chief bond of union between the vertebræ. They are twenty-three in number, and are interposed between the bodies of all the vertebræ from the epistropheus to the sacrum (figs. 260 and 271). Similar discs are found between the segments of the sacrum and coccyx in the younger stages of life, but they undergo ossification at their surfaces and often throughout their whole extent.

Each disc is composed of two portions—a circumferential laminar, and a central pulpy portion; the former tightly surrounds and braces in the latter, and forms somewhat more than half the disc. The **fibrous ring** [annulus fibrosus] or laminar portion consists of alternating layers of fibrous tissue and fibro-cartilage; the component fibres of these layers are firmly connected with two vertebræ, those of one passing obliquely down and to the right, those of the next down and to the left, making an X-shaped arrangement of the alternate layers. A few of the superficial lamellæ project beyond the edges of the bodies, their fibres being connected with the edges of the anterior and lateral surfaces; and some do not completely surround the rest, but terminate at the intervertebral foramina, so that on horizontal section the circumferential portion is seen to be thinner posteriorly. The more central lamellæ are incomplete, less firm, and not so distinct as the rest; and as they near the pulp they gradually assume its characters, becoming more fibro-cartilaginous and less fibrous, and have cartilage cells in their structure.

The **pulpy nucleus** [nucleus pulposus] or central portion is situated somewhat behind the centre of the disc, forming a ball of very elastic and tightly compressed material, which bulges freely when the confining pressure of the laminar portion is removed by either horizontal or vertical section. Thus, it has a constant tendency to spring out of its confinement in the direction of least resistance, and constitutes a pivot round which the bodies of the vertebræ can twist, tilt, or incline. It is yellowish in colour, and is composed of fine white and elastic

Fig. 265.—The Anterior Longitudinal Ligament, the Radiate, the Interarticular, and the Anterior Costo-transverse Ligaments.



fibres amidst which are ordinary connective-tissue cells, and peculiar cells of various sizes which contain one or more nuclei. Together with the most central laminæ, it is separated from immediate contact with the bone by a thin plate of articular cartilage. The central pulp of the intervertebral substance is the persistent part of the notochord.

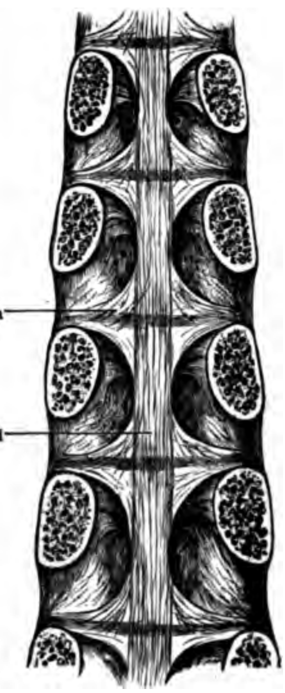
The intervertebral substances vary in shape with the bodies of the vertebræ they unite, and are widest and thickest in the lumbar region. In the cervical and lumbar regions they are thicker in front than behind, and *cause* the convexity forward of the cervical, and *increase* that of the lumbar; the curve in the thoracic region, almost entirely due to the shape of the bodies, is, however, somewhat increased by the discs. Without the discs the column loses a quarter of its length, and assumes a curve with the concavity forward, most marked a little below the mid-thoracic region. Such is the curve of old age, which is due to the shrinking and drying up of the intervertebral substances. The disc between the epistropheus and third cervical is the thinnest of all (fig. 260); that between the fifth lumbar and sacrum is the thickest, and is much thicker in front than behind (fig. 271). The intervertebral discs are in relation, in front with the anterior longitudinal ligament; behind, with the posterior longitudinal ligament; laterally, with the short lateral; and in the thoracic region, with the interarticular and radiate ligaments.

In the cervical region lateral diarthrodial joints are placed one on each side of the intervertebral discs. They are of small extent and are confined to the intervals between the prominent lateral lips of the upper surface of the body below and the bevelled lateral edges of the lower surface of the body above. Situated in front of the issuing spinal nerves and between those parts of the bodies formed from the neural arches, they are homologous with the joints between the atlas and epistropheus, and between the atlas and occipital bone.

The **anterior longitudinal ligament** (figs. 259 and 265) commences as a narrow band attached to the inferior surface of the occipital bone in the median line, just in front of the atlanto-occipital ligament, of which it forms the thickened central portion. Attached firmly to the tubercle of the atlas, it passes down as the central portion of the atlanto-epistrophic ligament, in the mid-line, to the front of the body of the epistropheus. It now begins to widen out as it descends, until it is nearly two inches (5 cm.) wide in the lumbar region. Below, it is fixed to the upper segment of the sacrum, becoming lost in periosteum about the middle of that bone; but is again distinguishable in front of the sacro-coccygeal joint, as the anterior sacro-coccygeal ligament.

Its structure is bright, pearly-white, and glistening. Its lateral borders are separated from the lateral bands by clefts through which blood-vessels pass; they are frequently indistinct and are best marked in the thoracic region. It is thickest in the thoracic region, and thicker in the lumbar than the cervical. It is firmly connected with the bodies of the vertebræ, and is composed of longitudinal fibres, of which the superficial extend over several, while the deeper pass over only two or three vertebræ. It is connected with the tendinous expansion of the pre-vertebral muscles in the cervical, and the crura of the diaphragm are closely attached to it in the lumbar region.

FIG. 266.—POSTERIOR LONGITUDINAL LIGAMENT. (Thoracic region.)
(Pedicles cut through, and posterior arches of vertebræ removed.)



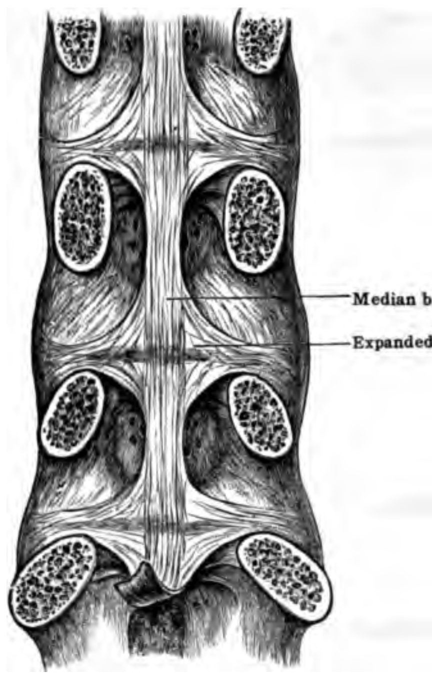
The **posterior longitudinal ligament** (figs. 263, 266, 267, and 274) extends from the occipital bone to the coccyx. It is wider above than below, and commences by a broad attachment to the cranial surface of the basi-occipital. In the cervical region it is of nearly uniform width, and extends completely across the bodies of the vertebræ, upon which it rests quite flat. It does, however, extend slightly further laterally on each side opposite the intervertebral discs. In the thoracic and lumbar regions it is distinctly dentated, being broader over the intervertebral substances and the edges of the bones than over the middle of the bodies, where it is a narrow band stretched over the bones without resting on them, the anterior internal vertebral venous plexus being interposed. The narrow median portion consists of longitudinal fibres, some of which are superficial and pass over several vertebræ; and others are deeper, and extend only from one vertebra to the next but one below.

The dentated or broader portions (fig. 267) are formed by oblique fibres which, springing from the bodies near the intervertebral foramina, take a curved course downward and back-

ward over an intervertebral fibro-cartilage, and reach the narrow portion of the ligament on the centre of the vertebra next below; they then diverge to pass over another intervertebral disc to end on the body of the vertebra beyond, near the intervertebral notch. They thus pass over two discs and three vertebræ. Deeper still are other fibres thickening these expansions of the longitudinal ligament, and extending from one bone to the next.

The last well-marked expansion is situated between the first two segments of the sacrum: below this, the ligament becomes a delicate central band with rudimentary expansions, being more pronounced again over the sacro-coccygeal joint, and losing itself in the ligamentous tissue at the back of the coccyx. The dura mater is tightly attached to it at the margin of the foramen magnum and behind the bodies of the upper cervical vertebræ, but is separated from it in the rest of its extent by loose cellular tissue which becomes condensed in the sacral region to form the sacro-dural ligament. The filum terminale becomes blended with it at the lower part of the sacrum and back of the coccyx.

FIG. 267.—POSTERIOR LONGITUDINAL LIGAMENT. (Lumbar region.)



The **lateral** (or short) **vertebral ligaments** (fig. 265) consist of numerous short fibres situated between the anterior and posterior longitudinal ligaments, and passing from one vertebra over the intervertebral disc, to which it is firmly adherent, to the next vertebra below.

The more superficial fibres are more or less vertical, but the deeper decussate and have a crucial arrangement. They are connected with the deep surface of the anterior longitudinal ligament, and so tie it to the edges of the bodies of the vertebræ and to the intervertebral discs. They blend behind with the expansions of the posterior longitudinal ligament, and so complete the casing round each amphiarthrodial joint. In the thoracic region, they overlie the radiate ligament, and in the lumbar they radiate toward the transverse processes. In the cervical region they are less well marked.

(b) THE LIGAMENTS CONNECTING THE ARTICULAR PROCESSES

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The **articular capsules** (fig. 259) which unite these processes are composed partly of yellow elastic tissue and partly of white fibrous tissue. In the cervical region only the medial side of the capsule is formed by the ligamenta flava, which in the thoracic and lumbar regions, however, extend anteriorly to the margins of the intervertebral foramina.

The part formed of white fibrous tissue consists of short, well-marked fibres, which in the cervical region pass obliquely downward and forward over the joint, between the articular proc-

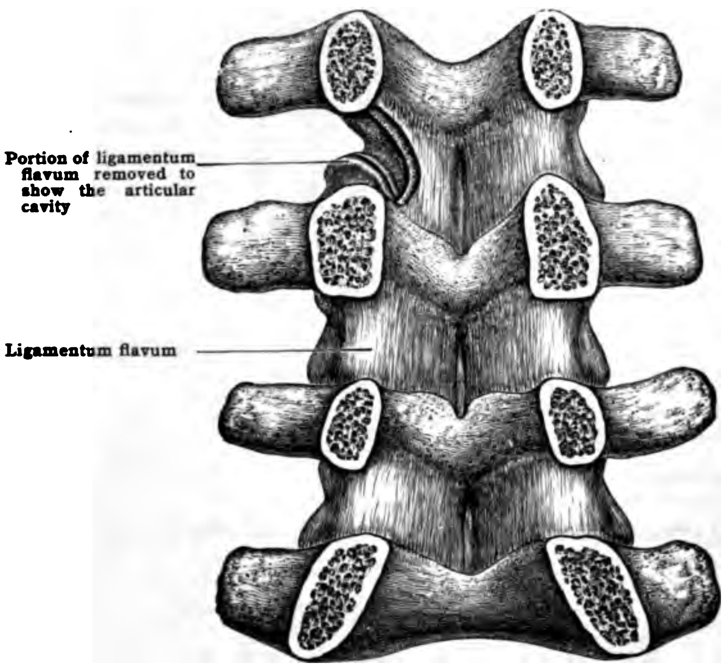
esses and the posterior roots of the transverse processes of two contiguous vertebræ. In the thoracic region the fibres are shorter, and vertical in direction, and are attached to the bases of the transverse processes; in the lumbar, they are obliquely transverse. The articular capsules in the cervical region are the most lax, those in the lumbar region are rather tighter, and those in the thoracic region are the tightest.

There is one **synovial membrane** to each capsule.

(c) The Ligaments uniting the Laminæ

The **ligamenta flava** (fig. 268) are thick plates of closely woven yellow elastic tissue, interposed between the laminæ of two adjacent vertebræ. The first connects the epistropheus with the third cervical, and the last the fifth lumbar with

Fig. 268.—Ligamenta Flava in the Lumbar Region, seen from within the Vertebral Canal.



the sacrum. Each ligament extends from the medial and posterior edge of the intervertebral foramen on one side to a corresponding point on the other; above, it is attached close to the inner margin of the inferior articular process and to a well-marked ridge on the inner surface of the laminæ as far as the root of the spine; below, it is fixed close to the inner margin of the superior articular process and to the dorsal aspect of the upper edge of the laminæ.

Thus each ligamentum flavum, besides filling up the interlaminar space, enters into the formation of two articular capsules; they do so to a greater extent in the thoracic and lumbar regions than in the cervical, where the articular processes are placed wider apart. When seen from the front after removing the bodies of the vertebræ, they are concave from side to side, but convex from above downward; they make a more decided transverse curve than the arches between which they are placed. This concavity is more marked in the thoracic, and still more in the lumbar region than in the cervical; in the lumbar region the ligamenta flava extend a short distance between the roots of the spinous process, blending with the interspinous ligament, and making a median sulcus when seen from the front; there is, however, no separation between the two parts. In the cervical region, where the spines are bifid, there is a median fissure in the yellow tissue which is filled up by fibro-areolar tissue. The ligaments are thickest and strongest in the lumbar region; narrow but strong in the thoracic; thinner, broader, and more membranous in the cervical region.

(d) The Ligaments connecting the Spinous Processes

These include supraspinous ligament, interspinous ligaments, and the ligamentum nuchæ.

The **supraspinous ligament** (fig. 270) extends without interruption as a well-marked band of longitudinal fibres along the tips of the spines of the vertebræ from that of the seventh cervical downward till it ends on the median sacral crest.

FIG. 269.—SIDE VIEW OF LIGAMENTUM NUCHÆ.

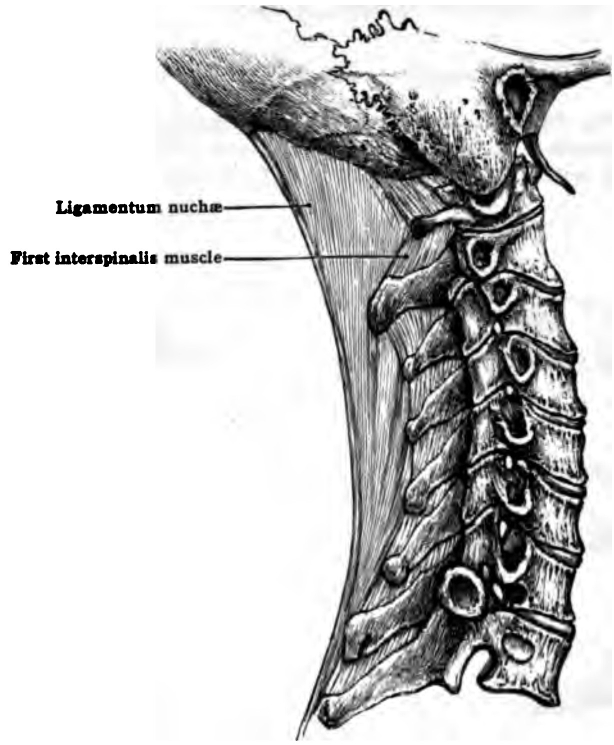
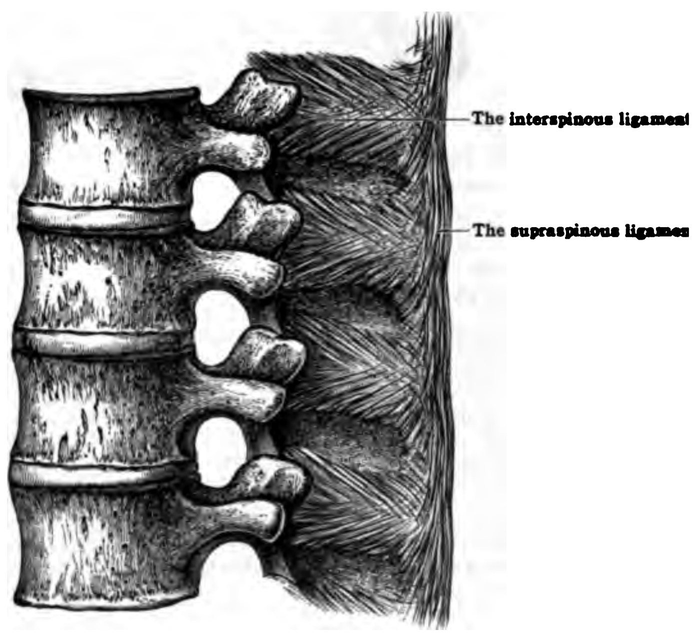


FIG. 270.—THE INTERSPINOUS AND SUPRASPINOUS LIGAMENTS IN THE LUMBAR REGION.



Its more superficial fibres are much longer than the deep. The deeper fibres pass ov adjacent spines only, while the superficial overlie several. It is connected laterally with t *aponeurotic structures* of the back; indeed, in the lumbar region, where it is well marked,

appears to result from the interweaving of the tendinous fibres of the several muscles which are attached to the tips of the spinous processes. In the dorsal region it is a round slender cord which is put on the stretch in flexion and relaxed in extension of the back.

The **ligamentum nuchæ,** or the posterior cervical ligament (fig. 269), is the continuation in the neck of the supraspinous ligament, from which, however, it differs considerably. It is a slender vertical septum of an elongated triangular form, extending from the seventh cervical vertebra to the external protuberance and the crest of the occipital bone. Its anterior border is firmly attached to the tips of the spines of all the cervical vertebræ, including the posterior tubercle of the atlas, as well as to the occiput. Its posterior border gives origin to the trapezii, with the tendinous fibres of which muscle it blends. Its lateral, triangular surfaces afford numerous points of attachment for the posterior muscles of the head and neck.

In man it is rudimentary, and consists of elastic and white fibrous tissues. As seen in the horse, elephant, ox, and other pronograde mammals, it is a great and important elastic ligament, which even reaches along the thoracic part of the spinal column. In these animals it serves to support the head and neck, which otherwise from their own weight would hang down. Its rudimentary state in man is the direct consequence of his erect position.

The **interspinous ligaments** (fig. 270) are thin membranous structures which extend between the spines, and are connected with the ligamenta flava in front, and the supraspinous ligament behind.

The fibres pass obliquely from the root of one spine to the tip of the next; they thus decussate. They are best marked in the lumbar region, and are replaced by the well-developed *interspinales* muscles in the cervical region.

(*e*) The Ligaments connecting the Transverse Processes

The **intertransverse ligaments** are but poorly developed.

In the thoracic region they form small rounded bundles, and in the lumbar they are flat membranous bands, unimportant as bonds of union. They consist of fibres passing between the apices of the transverse processes. In the cervical region they are replaced by the *intertransversarii* muscles.

The **arterial supply** for the column comes from twigs of the vertebral, ascending pharyngeal, ascending cervical, superior and aortic intercostals, lumbar, ilio-lumbar, and lateral sacral.

The **nerve-supply** comes from the spinal nerves of each region.

Movements.—The vertebral column is so formed of a number of bones and intervertebral discs as to serve many purposes. It is the axis of the skeleton; upon it the skull is supported; and with it the cavities of the trunk and the limbs are connected. As a fixed column it is capable of bearing great weight, and, through the elastic intervertebral substances, of resisting and breaking the transmission of shocks. Moreover, it is flexible. Now, the range of movements of the column as a whole is very considerable; but the movements between any two vertebræ are slight, so that motions of the spine may take place without any change in the shape of the column, and without any marked disturbance in the relative positions of the vertebræ. It is about the pulpy part of the intervertebral discs, which form a central elastic pivot or ball, upon which the middle of the vertebræ rest, that these movements take place.

The amount of motion is everywhere limited by the common vertebral ligaments, but it depends partly upon the width of the bodies of the vertebræ, and partly upon the depth of the discs, so that in the loins, where the bodies are large and wide, and the discs very thick, free motion is permitted; in the cervical region, though the discs are thinner, yet, as the bodies are smaller, almost equally free motion is allowed. As the ball-like pulpy part of the intervertebral disc is the centre of movement of each vertebra, it is obvious that the motion would be of a rolling character in any direction but for the articular processes, which serve also to give steadiness to the column and to assist in bearing the superincumbent weight. Were it not for these processes, the column, instead of being steady, endowed with the capacity of movement by muscular agency, would be tottering, requiring muscles to steady it. The influence of the articular processes in limiting the direction of inclination will appear from a study of the movements in the three regions of the spine.

In the **neck** all movements are permitted and are free, except between the second and third cervical vertebræ, where they are slight, owing to the shallow intervertebral disc and the great prolongation of the anterior lip of the inferior surface of the body of the epistropheus, which checks forward flexion considerably. On the whole, however, extension and lateral inclination are more free and extensive in this than in any other region of the column, whilst flexion is more limited than in the lumbar region. Rotatory movements are also free, but take place, on account of the position and inclination of the articular facets, not, as in the thoracic region, round a vertical axis, but round an oblique axis, the articular process of one side gliding upward and forward and that of the opposite side downward and backward.

In the **thoracic region,** especially near its middle, antero-posterior flexion and extension are very slight; and, as the concavity of the curve here is forward, the flat and nearly vertical surfaces of the articular processes prevent anything like sliding in a curvilinear manner of the

one set of processes over the sharp upper edges of the other, which would be necessary for forward flexion. A fair amount of lateral inclination would be permitted but for the impediment offered by the ribs; while the position and direction of the articular processes allows rotation round a vertical axis which passes through the centres of the bodies of the vertebræ. This rotation is not very great, and is freer in the upper than in the lower part of the thoracic region.

In the **lumbar region**, extension and flexion are very free, especially between the third and fourth and fourth and fifth vertebræ, where the lumbar curve is sharpest; lateral inclination is also very free between these same vertebræ. It has been stated that the shape and position of the articular processes of the lumbar and the lower two or three dorsal are such as to prevent any rotation in these regions; but, owing to the fact that the inferior articular processes are not tightly embraced by the superior, so that the two sets of articular processes are not in contact on both sides of the bodies at the same time, there is always some space in which horizontal motion can occur round an axis drawn through the central part of the bodies and intervertebral discs, but it is very slight. Thus, the motions are most free in those regions of the column which have a convex curve forward, due to the shape of the intervertebral discs, where there are no bony walls surrounding solid viscera, where the spinal canal is largest and its contents are less firmly attached, and where the pedicles and articular processes are more nearly on a transverse level with the posterior surface of the bodies of the vertebræ.

Nor must the uses of the ligamenta flava be forgotten: these useful structures—(1) complete the roofing-in of the vertebral canal, and yet at the same time permit an ever-changing variation in the width of the interlaminar spaces in flexion and extension; (2) they also restore the articulating surfaces to their normal position with regard to each other after movements of the column; (3) and by forming the medial portion of each articular capsule, they take the place of muscle in preventing it from being nipped between the articular surfaces during movement.

Muscles which take part in the movements of the vertebral column.—Flexors: When acting with their fellows of the opposite side. Rectus abdominis, infra-hyoid muscles (slightly) sterno-mastoid, external oblique, internal oblique, intercostals, scalenus anterior, psoas major and minor, longus colli, longus capitis (rectus capitis anterior major).

Extensors: When acting with their fellows of the opposite side. Sacro-spinalis, quadratus lumborum, semispinalis, multifidus, rotatores, interspinales, serrati posteriores, the splenius, and with the scapula fixed the levator scapulæ and the upper fibres of the trapezius.

Muscles which help to incline the column to their own side.—Sacro-spinalis, quadratus lumborum, semispinalis, multifidus, the intercostals helping to fix the ribs, the external and internal oblique muscles, levatores costarum, serrati posteriores, the scalenes, splenius cervicis, longus colli (oblique part), rotatores, intertransversales, psoas, and with the scapula fixed the levator scapulæ and the upper and lower fibres of the trapezius.

Muscles which rotate the column and turn the body to their own side.—Splenius cervicis, internal oblique (the ribs being fixed), serratus posterior inferior, and with the scapula fixed the lower fibres of the trapezius.

Muscles which rotate the column and turn the body to the opposite side.—Multifidus, semispinalis, external oblique, the lower oblique fibres of the longus colli, and with the scapula and humerus fixed the latissimus dorsi and trapezius.

2. THE SACRO-VERTEBRAL ARTICULATIONS

(*a*) **Class.**—*False Synchondrosis.*

(*b*) **Class.**—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

As in the intervertebral articulations, so in the union of the first portion of the sacrum with the last lumbar vertebra, there are two sets of joints—viz. (*a*) a synchondrosis, between the bodies and intervertebral disc; and (*b*) a pair of arthrodial joints, between the articular processes. The union is effected by the following ligaments, which are common to the vertebral column:—(i) anterior, and (ii) posterior longitudinal; (iii) lateral or short vertebral; (iv) capsular; (v) ligamenta flava; (vi) supraspinous and (vii) interspinous ligaments. Two special accessory ligaments on either side, viz., the sacro-lumbar and the ilio-lumbar, connect the pelvis with the fourth and fifth lumbar vertebræ.

The **sacro-lumbar ligament** (fig. 271) is strong, and triangular in shape. Its apex is above and medial, being attached to the whole of the lower border and front surface of the transverse process of the fifth lumbar vertebra, as well as to the pedicle and body. It is intimately blended with the *ilio-lumbar ligament*. Below, it has a wide, fan-shaped attachment, extending from the edge of the ilio-lumbar ligament forward to the brim of the true pelvis; blending with the periosteum on the base of the sacrum and in the iliac fossa, and with the superior sacro-iliac ligament.

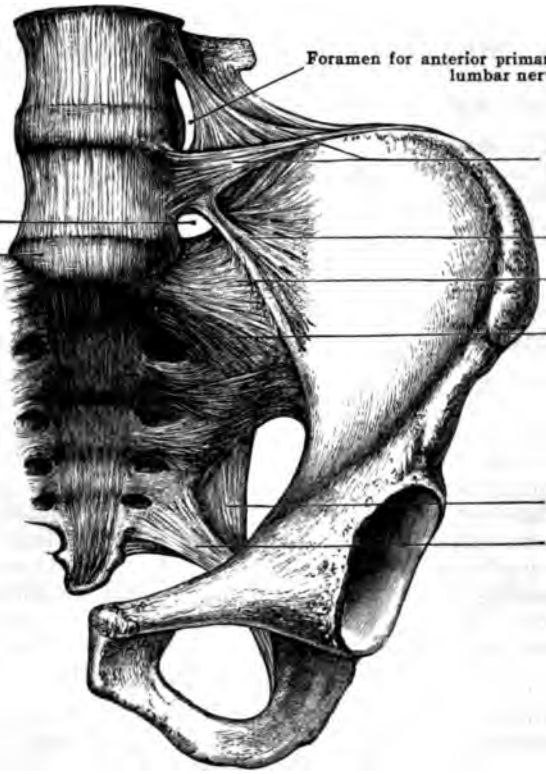
By its sharp medial border it limits laterally the foramen for the *last lumbar nerve*. It is pierced by two large foramina, which transmit arteries to the sacro-iliac synchondrosis. This ligament is in series with the intertransverse ligaments of the spinal column. It is sometimes described as a part of the ilio-lumbar ligament.

The **ilio-lumbar ligament** (fig. 271) is a strong, dense, triangular ligament connecting the fourth and fifth lumbar vertebræ with the iliac crest.

It springs from the front surface of the transverse process of the fifth lumbar vertebra as far as the body, by a strong fasciculus from the posterior surface of the process near the tip, and also from the front surface and lower edge of the transverse process and pedicle of the fourth lumbar vertebra, as far medialward as the body. Between these two lumbar vertebræ it is inseparable from the intertransverse ligament.

At its origin from the transverse process of the fifth lumbar vertebra it is closely interwoven with the sacro-lumbar ligament, and some of its fibres spread downward on to the body of the fifth vertebra, while others ascend to the disc above. At the pelvis it is attached to the inner lip of the crest of the ilium for about two inches (5 cm.). The highest fibres at the column form the upper edge of the ligament at the pelvis, those which come from the posterior portion of the transverse process of the fifth lumbar vertebra forming the lower, while the fibres from the front of the same process pass nearly horizontally lateralward. Near the column the surfaces

FIG. 271.—ANTERIOR VIEW OF THE LIGAMENTS BETWEEN VERTEBRÆ AND PELVIS.



look directly backward and forward, but at the ilium the ligament gets somewhat twisted, so that the posterior surface looks a little upward, and the anterior looks a little downward. The anterior surface forms part of the posterior boundary of the major (false) pelvis, and overlies the upper part of the posterior sacro-iliac ligament; the posterior surface forms part of the floor of the spinal groove, and gives origin to the *multifidus* muscle. Of the borders, the upper is oblique, has the anterior lamella of the lumbar fascia attached to it, and gives origin to the *quadratus lumborum;* the lower is horizontal, and is adjacent to the upper edge of the sacro-lumbar ligament; while the medial is crescentic, and forms the lateral boundary of a foramen through which the *fourth lumbar* nerve passes.

The **arterial supply** is very free, and comes from the last lumbar, ilio-lumbar, and lateral sacral.

The **nerve-supply** is from the sympathetic, as well as from twigs from the fourth and fifth lumbar nerves.

Movements.—The angle formed by the sacrum with the spinal column is called the sacro-vertebral angle. The pelvic inclination does not depend entirely upon this angle, but in great part upon the obliquity of the coxal (innominate) bones to the sacrum, so that in males in whom the average pelvic obliquity is a little greater, the average sacro-vertebral angle is considerably less than in females.

The sacro-vertebral angle in the male shows that there is a greater and more sudden change in direction at the sacro-vertebral union than in the female. A part of this change in direction is due to the greater thickness in the anterior part of the intervertebral fibro-cartilage between the last lumbar vertebra and the sacrum. Owing to the greater thickness of the intervertebral

disc here than elsewhere, the movements permitted at this joint are very free, being freer than those between any two lumbar vertebræ. As the diameter of the two contiguous bones is less in the sagittal than in the frontal plane, the forward and backward motions are much freer than those from side to side. The backward and forward motions take place every time the sitting is exchanged for the standing position, and the standing for the sitting posture; in rising, the back is extended on the sacrum at the sacro-lumbar union; in sitting down it is flexed.

The articular processes provide for the gliding movement incidental to the extension, flexion, and lateral movements; they also allow some horizontal movement, necessary for the rotation of the vertebral column on the pelvis, or pelvis on the column. The inferior articular processes of the fifth differ considerably from the inferior processes in the rest of the lumbar vertebræ, and in direction they resemble somewhat those of the cervical vertebræ; while the superior articular processes of the sacrum differ in a similar degree from the superior processes of the lumbar vertebræ. This difference allows for the freer rotation which occurs at this joint.

The sacro-vertebral angle averages 117° in the male, and 130° in the female; while the pelvic inclination averages 155° in the male, and 150° in the female.

As already stated, the movements at the sacro-vertebral joint are the same as those in other parts of the spinal column, but more extensive, and the muscles which produce the movements are those mentioned in the preceding groups which cross the plane of the articulation.

3. THE ARTICULATIONS OF THE PELVIS

This group may again be subdivided into—

(*a*) The **sacro-iliac.**
(*b*) The **sacro-coccygeal.**
(*c*) The **intercoccygeal.**
(*d*) The **symphysis pubis.**

(*a*) The Sacro-iliac Articulation and Sacro-sciatic Ligaments

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

It is now generally admitted that the sacro-iliac joint is a diarthrosis, the articular surface of each bone being covered with a layer of cartilage, whilst the cavity of the joint is a narrow cleft and the capsule is extremely thick posteriorly. The cartilage on the sacrum is much thicker than that on the ilium and the cartilages are sometimes bound together here and there by fibrous strands. The different character of the joint in the two sexes should be noted. Briefly, the female joint has strong ligamentous bonds with but little bony apposition, while the male joint gains its strength by virtue of extensive areas of bony contact and a slighter development of ligaments. This difference is, of course, a physiological one; for some laxity of the joint is demanded during pregnancy and labour. The bones which enter into the joint are the sacrum and ilium, and they are bound together by the following ligaments:—

Anterior sacro-iliac.	Superior sacro-iliac.
Posterior sacro-iliac.	Inferior sacro-iliac.

Interosseous.

The **anterior sacro-iliac ligament** (figs. 271 and 272) consists of well-marked glistening fibres which pass above into the superior, and below into the inferior, ligaments. It extends from the first three bones of the sacrum to the ilium between the brim of the pelvis minor and the great sciatic notch, blending with the periosteum of the sacrum and ilium as it passes away from the united edges of the bones.

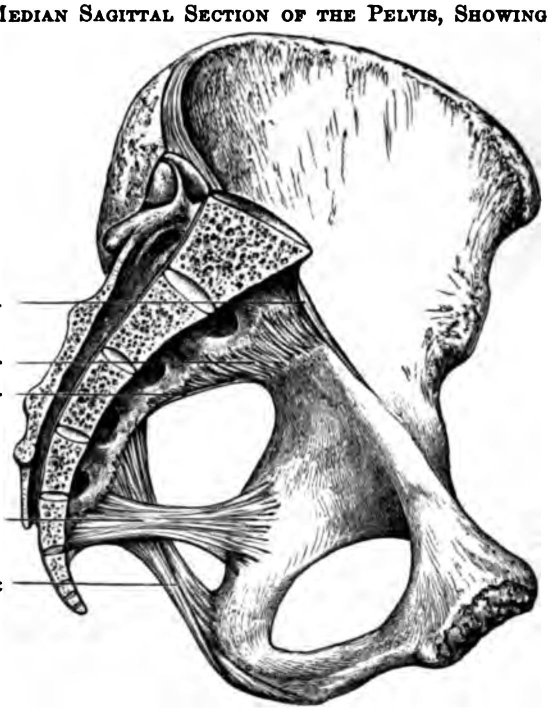
The **superior sacro-iliac ligament** (figs. 271 and 272) extends across the upper margins of the joint, from the ala of the sacrum to the iliac fossa, being well marked along the brim of the pelvis, where it is thickened by some closely packed fibres. Behind, it is far stronger, especially beneath the transverse process of the fifth lumbar vertebra. This ligament is connected with the strong sacro-lumbar ligament, which spreads lateralward and forward over the joint to reach the iliac fossa and terminal line. By some authors it is described as a part of the ilio-lumbar ligament.

The **posterior sacro-iliac ligament** is extremely strong and consists essentially of two sets of fibres, deep and superficial. The deep fibres (short posterior sacro-iliac ligament) pass downward and medialward from the rough area of the

ilium behind the auricular surface to the back of the lateral mass of the sacrum, both lateral to and between the upper foramina and to the upper sacral articular process, and the area between it and the first sacral foramen. The deepest fibres of this group constitute the so-called interosseous ligament. The more superficial fibres (long posterior sacro-iliac ligament) are oblique or vertical, and pass from the posterior superior iliac spine to the second, third, and fourth tubercles on the back of the sacrum, a more or less well-defined band which goes to the third and fourth sacral tubercles being called sometimes the oblique sacro-iliac band and sometimes the long straight band.

The **inferior sacro-iliac ligament** (fig. 272) is covered behind by the upper end of the sacro-tuberous ligament; it consists of strong fibres extending from the lateral border of the sacrum below the articular facet to the posterior iliac spines; some of the fibres are attached to the deep surface of the ilium and join the interosseous ligament.

FIG. 272.—MEDIAN SAGITTAL SECTION OF THE PELVIS, SHOWING LIGAMENTS.



The **interosseous ligament** is the strongest of all, and consists of fibres of different lengths passing in various directions between the two bones. Immediately above the interspinous notch of the ilium the fibres of this ligament are very strong, and form an open network, in the interstices of which is a quantity of fat in which the articular vessels ramify.

The ear-shaped **cartilaginous plate,** which unites the bones firmly, is accurately applied to the auricular surfaces of the sacrum and ilium. It is about one-twelfth of an inch (2 mm.) thick in the centre, but becomes thinner toward the edges. Though closely adherent to the bones, it tears away from one entirely, or from both partially, on the application of violence, sometimes breaking irregularly so that the greater portion remains connected with one bone, leaving the other bone rough and bare. It is usually one mass, and is only occasionally formed of two plates with a synovial cavity between them.

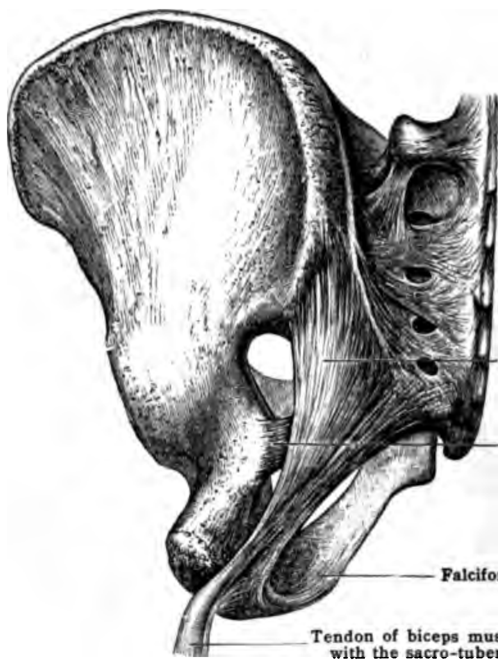
Because of the occasional presence of a more or less extensive synovial cavity within the fibro-cartilage, and also of a synovial lining to the ligaments passing in front and behind the articulation, the term 'diarthro-amphiarthrosis' has been given to this joint, and also to the symphysis pubis. Testut mentions certain folds of synovial membrane filling up gaps which here and there occur at the margin of the fibro-cartilage but they are not usually seen.

The **sacro-tuberous** (great sciatic) **ligament** (figs. 271, 272, and 273) is attached above to the posterior extremity of the crest of the ilium and the lateral aspect of the posterior iliac spines. From this attachment some of its fibres

pass downward and backward to be attached to the lateral borders and posterior surfaces of the lower three sacral vertebræ and upper two segments of the coccyx; while others, after passing for a certain distance backward, curve forward and downward to the ischium, forming the anterior free margin of the ligament where it limits posteriorly the sciatic foramina. These fibres are joined by others which arise from the posterior surfaces of the lower three sacral vertebræ and upper pieces of the coccyx. At the ischium it is fixed to the medial border of the tuberosity, and sends a thin sharp process upward along the ramus of the ischium which is called the **falciform process** (fig. 273), and is a prolongation of the posterior edge of the ligament.

A great many fibres pass on directly into the tendon of the biceps muscle, so that traction on this muscle braces up the whole ligament, and the coccyx is thus made to move on the sacrum. The ligament may not unfairly be described as a tendinous expansion of the muscle, whereby its action is extended and a more advantageous leverage given. It is broad and flat at its attached ends, but narrower and thicker in the centre, looking like two triangular expansions

FIG. 273.—SACRO-TUBEROUS AND SACRO-SPINOUS LIGAMENTS. (Posterior view.)



joined by a flat band, the larger triangle being at the ilium, and the smaller at the ischium The fibres of the ligament are twisted upon its axis at the narrow part, so that some of the superior fibres pass to the lower border.

The posterior surface gives origin to the *gluteus maximus* muscle, and on it ramify the loop; from the posterior branches of the sacral nerves; its anterior surface is closely connected at its origin ,with the sacro-spinous ligament, and some fibres of the *piriformis* muscle arise from its below the *obturator internus* passes out of the pelvis under its cover, and the *internal pudic vessels and nerve* pass in. At the ilium, its posterior edge is continuous with the vertebra. aponeurosis; while to the anterior edge is attached the thick fascia covering the gluteus mediul The obturator fascia is attached to its falciform edge. It is pierced by the *coccygeal branches of the inferior gluteal* (*sciatic*) *artery* and the *inferior clunial* (*perforating cutaneous*) *nerve* from the *second* and *third sacral*.

The **sacro-spinous** (small sciatic) **ligament** (figs. 271, 272, and 273) is triangular and thin, springing by a broad base from the lateral border of the sacrum and coccyx, from the front of the sacrum both above and below the level of the fourth sacral foramen, and from the coccyx nearly as far as its tip. By its apex it is attached to the front surface and the borders of the ischial spine as far outward as its base. Its fibres decussate so that the lower ones at the coccyx become the highest at the ischial spine; muscular fibres are often seen intermingled with the ligamentous.

The sacro-spinous ligament is situated in front of the sacro-tuberous ligament, with which it is closely connected at the sacrum, and separates the greater from the lesser sciatic foramen.

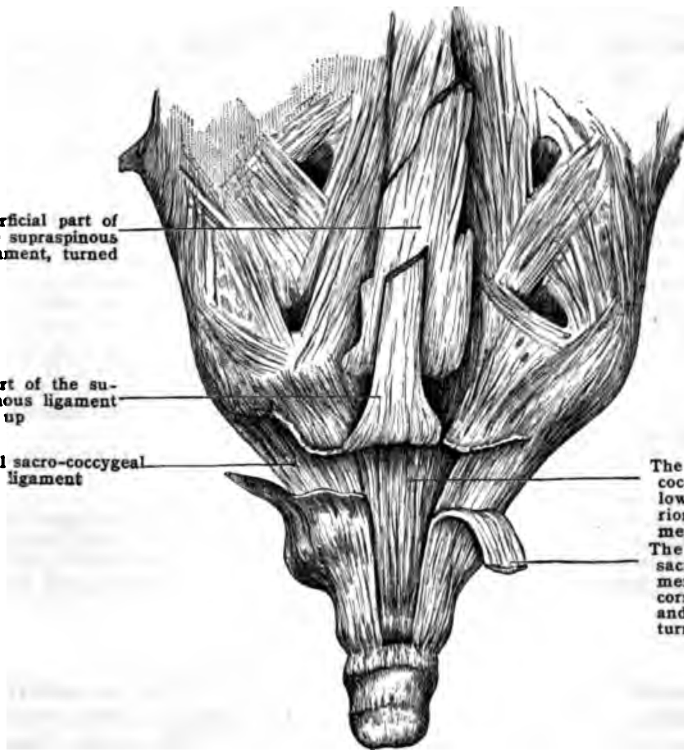
Its front surface gives attachment to the *coccygeus* muscle, which overlies it. Behind, it is connected with, and hidden by, the sacro-tuberous ligament, so that only the lateral inch or less (2 cm.) and a small part of its attachment to the coccyx can be seen; the *internal pudic* nerve also passes over the posterior surface.

The **arterial supply** of the sacro-iliac joint comes from the superior gluteal, ilio-lumbar, and lateral sacral.

The **nerve-supply** is from the superior gluteal, sacral plexus, and external twigs of the posterior divisions of the first and second sacral nerves.

Movements.—Recent investigations have shown that in spite of the interlocking of the articular surfaces and the strong ligaments connecting the bones together a slight amount of movement, both a gliding and rotatory, does occur at the sacro-iliac joint. The gliding movement is both up and down, and forward and backward, and the latter is associated with a slight rotation round a transverse axis which passes through the upper tubercles on the back of the sacrum. The movement is but small in extent, nevertheless as the base of the sacrum moves

FIG. 274.—LIGAMENTS CONNECTING SACRUM AND COCCYX POSTERIORLY.



downward and forward the conjugate (antero-posterior) diameter of the pelvic inlet is diminished and at the same time, as the coccyx moves up and back, the conjugate diameter of the outlet is increased. This rotatory movement is limited principally by the sacro-sciatic (sacro-tuberous and sacro-spinous) ligaments which prevent any extensive upward and backward movement of the coccyx and lower part of the sacrum.

Downward displacement of the sacrum when the body is in the sitting posture is prevented not only by the surrounding ligaments, but also by the wedge-like character of the sacrum, which is broader above than below. Downward and forward displacement of the sacrum in the erect posture is prevented by the ligaments and more particularly by the posterior sacro-iliac bands, while backward displacement would be hindered by the breadth of the anterior as contrasted with the posterior part of the sacrum as well as by the anterior ligaments.

Relations.—The sacro-iliac joint is in relation above with psoas and iliacus. In front it is in relation at its upper part with the hypogastric vessels and obturator nerve, and at its lower part with the piriformis muscle.

(*b*) THE SACRO-COCCYGEAL ARTICULATION

Class.—*False Synchondrosis.*

The last piece of the sacrum and first piece of the coccyx enter into this union [symphysis sacrococcygea] and are bound together by the following ligaments:—

Anterior sacro-coccygeal. Deep posterior sacro-coccygeal.
Superficial posterior sacro-coccygeal. Lateral sacro-coccygeal.
Intervertebral substance.

The **intervertebral fibro-cartilage** is a small oval disc, three-quarters of an inch (about 2 cm.) wide, and a little less from before backward, closely connected with the surrounding ligaments. It resembles the other discs in structure, but is softer and more jelly-like, though the laminæ of the fibrous portion are well marked.

The **anterior sacro-coccygeal ligament** is a prolongation of the glistening fibrous structure on the front of the sacrum. It is really the lower extremity of the anterior longitudinal ligament, which is thicker over this joint than over the central part of either of the bones.

The **posterior sacro-coccygeal ligament** (fig. 274) is divided into two layers of which one (the **deep**) is a direct continuation of the posterior longitudinal ligament of the column, consisting of a narrow band of closely packed fibres, which become blended at the lower border of the first segment of the coccyx with the filum terminale and deep posterior ligament.

The **superficial layer** of the posterior sacro-coccygeal ligament (or supracornual ligament), (fig. 274) is the prolongation of the supraspinous which becomes inseparably blended with the aponeurosis of the *sacro-spinalis* (*erector spinæ*) opposite the laminæ of the third sacral vertebra, and is thus prolonged downward upon the back of the coccyx, passing over and roofing in the lower end of the spinal canal where the laminæ are deficient.

The median fibres (the **supraspinous ligament**) extend over the back of the coccyx to its tip, blending with the deep fibres of the posterior sacro-coccygeal ligament and filum terminale; the deeper fibres run across from the stunted laminæ on one side to the next below on the opposite side, and from the sacral cornua on one side to the coccygeal on the opposite, some passing between the two cornua of the same side, and bridging the aperture through which the fifth sacral nerve passes. Its posterior surface gives origin to the *gluteus maximus* muscle.

The **lateral sacro-coccygeal** or **intertransverse ligament** (fig. 274) is merely a quantity of fibrous tissue which passes from the transverse process of the coccyx to the lateral edge of the sacrum below its angle. It is connected with the sacrosciatic ligaments at their attachments, and the *fifth sacral* nerve escapes behind it. It is perforated by twigs from the lateral sacral artery and the coccygeal nerve.

The **arterial supply** of the sacro-coccygeal joint is from the lateral sacral and middle sacral arteries.

The **nerves** come from the fourth and fifth sacral and coccygeal nerves.

The **movements** permitted at this joint are of a simple forward and backward, or hinge-like character. In the act of defecation, the bone is pushed back by the fæcal mass, and, in parturition, by the fœtus; but this backward movement is controlled by the upward and forward pull of the levator ani and coccygeus. The external sphincter also tends to pull the coccyx forward.

(c) Intercoccygeal Joints

The several segments of the coccyx are held together by the anterior and posterior longitudinal ligaments, which completely cover the bony nodules on their anterior and posterior aspects. Laterally, the sacro-sciatic ligaments, being attached to nearly the whole length of the coccyx, serve to connect them. Between the first and second pieces of the coccyx there is a very perfect amphiarthrodial joint, with a well-marked intervertebral substance.

Movements.—But little movement occurs as a rule at the sacro-coccygeal and intercoccygeal joints, but when the head of the child is passing through the pelvic outlet at birth, the tip of the coccyx is displaced backward, it may be to the extent of one inch.

(d) The Symphysis Pubis

Class.—*False Synchondrosis.*

The bones entering into this joint are the pubic portions of the hip-bones. This joint is shorter and broader in the female than in the male. The ligaments, which completely surround the articulation, are:—

Superior.	Anterior.
Arcuate.	Posterior.
Interpubic cartilage.	

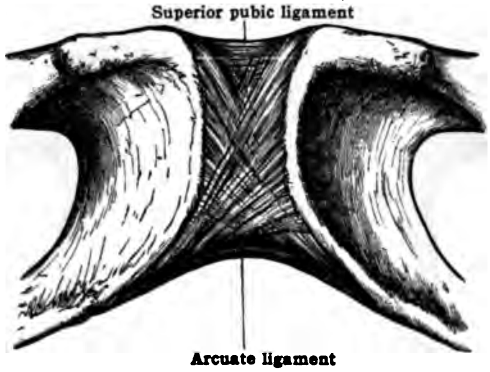
The **superior ligament** (figs. 275 and 276) is a well-marked stratum of yellowish fibres which extends lateralward along the crest of the pubis on each side, blending in the middle line with the interosseous cartilage.

It is continuous in front with the deep traverse fibres of the anterior ligament, and behind with the posterior ligament. It gives origin to the *rectus abdominis* tendon.

The **posterior ligament** (fig. 277) is slight, and, excepting above and below, consists of little more than thickened periosteum.

Near the upper part is a band of strong fibres, reaching the whole width of the pubic bones, and continuous with the thickened periosteal fibres along the terminal line. Below, many of the upper and superficial fibres of the arcuate ligament ascend over the back of the joint, and interlace across the median line with fibres from the opposite side nearly as high as the middle of the symphysis.

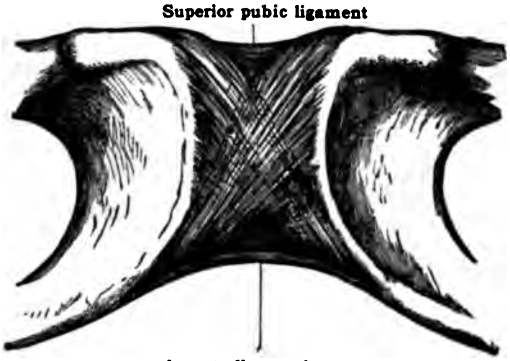
FIG. 275.—ANTERIOR VIEW OF THE SYMPHYSIS PUBIS (MALE), SHOWING THE DECUSSATION OF THE FIBRES OF THE ANTERIOR LIGAMENT.



The **anterior ligament** (figs. 275 and 276) is thick and strong, and is closely connected with the fascial covering of the muscles arising from the body of the pubis. It consists of several strata of thick, decussating fibres of different degrees of obliquity, the superficial being the most oblique, and extending lowest over the joint.

The most superficial descending fibres extend from the upper border of the pubis, cross others from the opposite side about the middle of the symphysis, and are attached to the ramus of the opposite bone. The most superficial ascending fibres come from the arcuate ligament,

FIG. 276.—ANTERIOR VIEW OF THE SYMPHYSIS PUBIS (FEMALE), SHOWING GREATER WIDTH BETWEEN THE BONES.



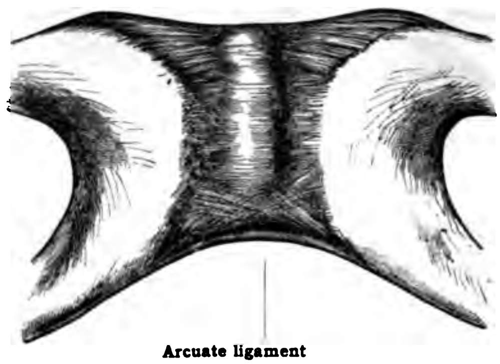
arch upward, and decussate with other fibres across the middle line, and are lost on the opposite side beneath the descending set. There is another deeper set of descending fibres which arise below the angle, but do not descend so far as the superficial; and a deeper set of ascending, which decussate, and reach higher than the superficial set, and are connected with the arcuate ligament. Some few transverse fibres pass from side to side, especially above and below the points of decussation.

The **arcuate** (inferior or subpubic) **ligament** (figs. 275, 276, and 277) is a thick, arch-like band of closely packed fibres which fills up the angle between the pubic rami, and forms a smooth, rounded summit to the pubic arch. On section, it is yellowish in colour and three-eighths of an inch (1 cm.) thick in the middle line; it is inseparably connected with the interpubic cartilage.

Both on the front and back aspects of the joint it gives off decussating fibres, which, by their interlacement over the anterior and posterior ligaments of the symphysis, add very materially to its security. In fact, the ligament may be said to split superiorly into two layers, one passing over the front, and the other over the back, of the articulation.

The **interpubic fibro-cartilage** varies in thickness in different subjects, but is thicker in the female than in the male. It is thicker in front than behind, and projects beyond the edges of the bones, especially posteriorly (see fig. 277), blending intimately with the ligaments at its margins. It is sometimes uninterruptedly woven throughout, but at others has an elongated narrow fissure, partially dividing the cartilage into two plates, with a little fluid in the interspace

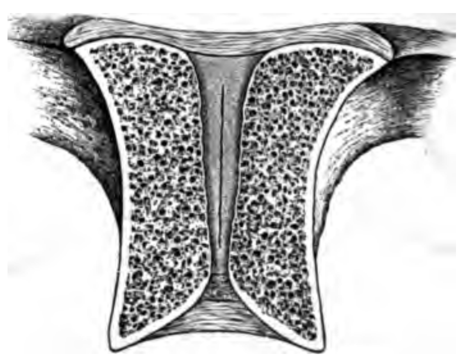
FIG. 277.—POSTERIOR VIEW OF THE SYMPHYSIS PUBIS, SHOWING THE DECUSSATION OF THE FIBRES FROM THE ARCUATE LIGAMENT.



(fig. 278). This is situated toward the upper and posterior aspects, but does not usually reach either; it generally extends about half the length of the cartilage.

When this cavity is large, especially if it reaches or approaches very near to the circumference of the cartilage (which, however, it very rarely does), it is thought by some anatomists that it more nearly resembles a diarthrodial than an amphiarthrodial joint, and it is then classed with the sacro-iliac joint under similar conditions, as 'diarthroamphiarthrosis.' The interosseous cartilage is intimately adherent to the layer of hyaline cartilage which covers the medial surface of each pubic bone; the osseous surface is ridged to give a firmer attachment; and, on forcing the bones apart, it does not frequently split into two plates, but is torn from the bone on one side or the other.

FIG. 278.—SECTION OF SYMPHYSIS TO SHOW THE SYNOVIAL CAVITY.



The **arterial supply** of the interpubic joint is from twigs of the internal pudic, pubic branches of the obturator and epigastric, and ascending branches of the internal circumflex and superficial external pudic.

The **nerve-supply** has not been satisfactorily made out, but it probably comes, in part, from the internal pudic and in part from the ilio-hypogastric and ilio-inguinal.

The **movements** amount only to a slight yielding of the cartilage; neither muscular force nor extrinsic forces produce any appreciable movement in the ordinary condition. Occasionally, as the result of child-bearing, the joint becomes unnaturally loose, and then walking and standing are painfully unsteady. It is known that, during pregnancy and parturition, the

symphyseal cartilage becomes softer and more vascular, so as to permit the temporary enlargement of the pelvis; but it must be remembered that the fibres of the oblique muscles decussate and thus, during labour, while they force the head of the fœtus down, they strengthen the joint by bracing the bones more tightly together.

Relations.—The interpubic joint is in relation above with the linea alba. Behind with the prostate and the anterior border of the bladder. In front with the suspensory ligament of the penis or clitoris and below with the dorsal vein of the penis or clitoris and the upper border of the urogenital trigone (triangular ligament).

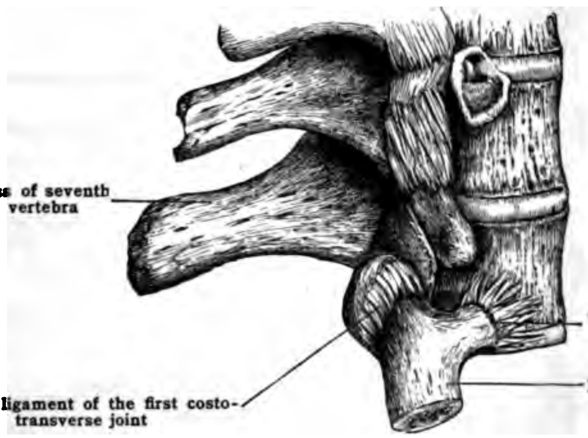
4. THE COSTO-VERTEBRAL ARTICULATIONS

These consist of two sets, viz.:—

(*a*) The **capitular** (costo-central): i. e., the articulation of the head of the rib with the vertebræ.

(*b*) The **costo-transverse,** or the articulation of the tubercle (of each of the first ten ribs) with the transverse process of the lower of the two vertebræ, with which the head of the rib articulates: i. e., the one bearing its own number, as the first rib with the first thoracic vertebra, the second rib with the second thoracic vertebra, and so on.

FIG. 279.—THE CAPSULAR LIGAMENTS OF THE COSTO-VERTEBRAL JOINTS.



(*a*) THE CAPITULAR (COSTO-CENTRAL) ARTICULATION

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

It is a very perfect joint, into the formation of which the head of the rib and two vertebræ, with the intervertebral disc between them, enter. In the case of the first, tenth, eleventh, and twelfth ribs, it is formed by the head of the rib articulating with a single vertebra.

The **ligaments** are:—

Articular capsule. Interarticular.
Radiate.

The **articular capsule** (fig. 279) consists of short, strong, woolly fibres, completely surrounding the joint, which are attached to the bones and intervertebral substances, a little beyond their articular margins.

At its upper part it reaches through the intervertebral foramen toward the back of the bodies of the vertebræ, being strengthened here by fibres which at intervals connect the anterior with the posterior longitudinal ligaments. The lower fibres extend downward nearly to the demi-facet (costal pit) of the rib below; behind, it is continuous with the neck ligament, and in front is overlaid by the radiate.

The **interarticular ligament** (fig. 280) consists of short, strong fibres, closely interwoven with the outermost ring of the intervertebral disc, and attached to the transverse ridge separating the articular facets on the head of the rib. It completely divides the articulations into two parts, but does not brace the rib tightly to the spine, being loose enough to allow a moderate amount of rotation

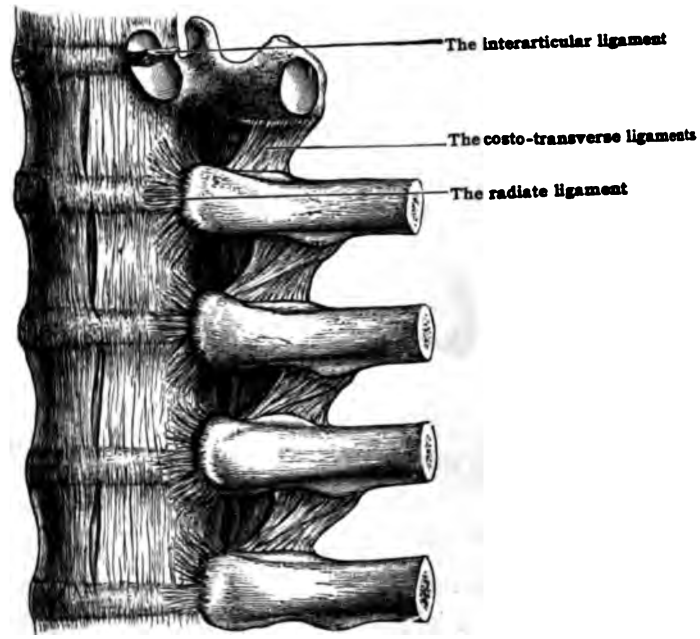
on its own axis. There is no interarticular ligament in the costo-vertebral joints of the first, tenth, eleventh, and twelfth ribs.

The **radiate** (or stellate) **ligament,** a thickening of the anterior part of the capsule (figs. 280 and 281), is the most striking of all, and consists of bright, pearly-white fibres attached to the anterior surface, and upper and lower borders of the neck of the rib, a little way beyond the articular facet; from this they radiate upward, forward, and downward, so as to form a continuous layer of distinct and sharply defined fibres.

The middle fibres run straight forward to be attached to the intervertebral disc; the upper ascend to the lower half of the lateral surface of the vertebra above, and the lower descend to the upper half of the vertebra below. The radiate ligament is overlapped on the vertebral bodies by the lateral (short) vertebral ligaments.

In the case of the first, tenth, eleventh, and twelfth ribs, each of which articulates with one vertebra, the ligament is not quite so distinctly radiate, but even in these the ascending fibres reach the vertebra above that with which the rib articulates.

Fig. 280.—Showing the Anterior Longitudinal Ligament, and the Connection of the Ribs with the Vertebræ.



The **synovial membranes** (fig. 281) consist of two closed sacs which do not communicate: one above, and the other below, the interarticular ligament. In the case of the first, tenth, eleventh, and twelfth articulations, there is but one synovial membrane, as these joints have no interarticular ligament.

The **arterial supply** is from the intercostal arteries, the twigs piercing the radiate and capsular ligaments.

The **nerve-supply** comes from the anterior primary branches of the intercostal nerves.

These joints approach most nearly in their movements to the condylarthroses.

The **movements** are ginglymoid in character, consisting of a slight degree of elevation and depression around an obliquely horizontal axis corresponding with the interarticular ligament; there is also a slight amount of forward and backward gliding; and a slight degree of screwing or rotatory movement is also possible. There is a considerable difference in the degree of mobility of the different ribs, for while the first rib is almost immobile except in a very deep inspiration, the mobility of the others increases from the second to the last; the two floating ribs being the most mobile of all. The head of the rib is the most fixed point of the costal arch, and upon it the whole arch rotates; the interarticular ligament allows only a very limited amount of flexion and extension (i. e., elevation and depression), and of gliding. Gliding is checked by the radiate ligament.

In inspiration, the rib is elevated, and glides forward in its socket, too great elevation being checked not only by the ligaments, but also by the overhanging upper edge of the cavity *itself.* In expiration, the rib is depressed, and glides backward in its cavity.

(*b*) The Costo-transverse Articulation

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

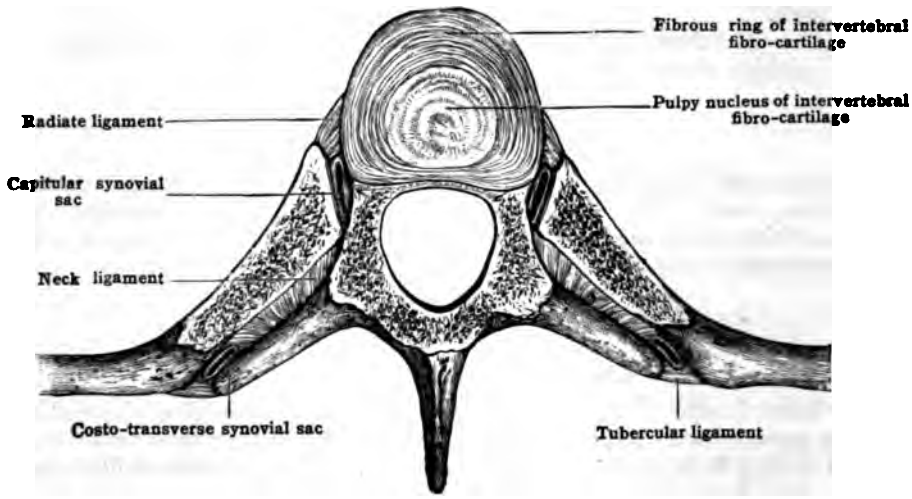
This joint is formed by the tubercle of the rib articulating with the anterior part of the tip of the transverse process. The eleventh and twelfth ribs are devoid of these joints, for the tubercles of these ribs are absent, and the transverse processes of the eleventh and twelfth thoracic vertebræ are rudimentary.

The ligaments of the union are:—

Articular capsule.	Tubercular ligament.
Neck ligament.	Costo-transverse ligaments.

The **articular capsule** (figs. 279 and 281) forms a thin, loose, fibrous envelope to the synovial membrane. Its fibres are attached to the bones just beyond the articular margins, and are thickest below, where they are not strengthened by any other structure. It is connected medially with the neck ligament, above with the costo-transverse, and laterally with the tubercular (posterior costo-transverse) ligaments. The **eleventh** and **twelfth ribs** are unprovided with costo-transverse capsules.

Fig. 281.—Horizontal Section through the Intervertebral Disc and Ribs.



The **neck ligament** [lig. colli costæ] (middle costo-transverse, or interosseous ligament) (fig. 281), consists of short fibres passing between the back of the neck of the rib and front of the transverse process, with which the tubercle articulates. It extends from the capsule of the capitular joint to that of the costo-transverse. It is best seen on horizontal section through the bones. In the **eleventh** and **twelfth** ribs this ligament is rudimentary.

The **tubercular ligament** (posterior costo-transverse) (fig. 281) is a short but thick, strong, and broad ligament, which extends laterally and upward from the extremity of the transverse process to the non-articular surface of the tubercle of the corresponding rib. The **eleventh** and **twelfth** ribs have no posterior ligament.

The (superior) **costo-transverse ligament** (fig. 280) is a strong, broad band of fibres which ascends laterally from the **crest** on the upper border of the neck of the rib, to the lower border of the transverse process above. A few scattered posterior fibres pass upward and medially from the neck to the transverse process. The costo-transverse ligament is subdivided into a stronger anterior portion (anterior costo-transverse ligament) best seen from the front (fig. 280), and a weaker posterior portion (posterior costo-transverse ligament). Its medial border bounds the foramen through which the posterior branches of the intercostal vessels and nerves pass. To the lateral border is attached the thin aponeu-

rosis covering the *external intercostals*. Its anterior surface is in relation with the intercostal vessels and nerve; the posterior with the *longissimus dorsi*. The **first** rib has no (superior) costo-transverse ligament.

The synovial membrane (fig. 281) is a single sac.

The arterial and nerve supplies come from the posterior branches of the intercostal arteries and nerves.

The movements which take place at these joints are limited to a gliding of the tubercle of the rib upon the transverse process. The exact position of the facet on the transverse process varies slightly from above downward, being placed higher on the processes of the lower vertebræ. The plane of movement in most of the costo-transverse joints is inclined upward and backward in inspiration, and downward and forward in expiration. The point round which these movements occur is the head of the rib, so that the tubercle of the rib glides upon the transverse process in the circumference of a circle, the centre of which is at the capitular joint.

5. THE ARTICULATIONS AT THE FRONT OF THE THORAX

These may be divided into four sets, viz.:—

(*a*) The **intersternal joints,** or the union of the several parts of the sternum with one another.

(*b*) The **costo-chondral joints,** or the union of the ribs with their costal cartilages.

(*c*) The **chondro-sternal joints,** or the junction of the costal cartilages with the sternum.

(*d*) The **interchondral joints,** or the union of five costal cartilages (sixth, seventh, eighth, ninth, and tenth) with one another.

(*a*) The Intersternal Joints

The sternum being composed, in the adult, of three distinct pieces—the manubrium, body, and the xiphoid process—has two articulations, viz., the superior, which unites the manubrium with the body (gladiolus), and the inferior, which unites the body with the xiphoid.

1. The Superior Intersternal Articulation

Class.—*False Synchondrosis.*

The lower border of the manubrium and the upper border of the body of the sternum present oval-shaped, flat surfaces, with their long axes transverse, and covered with a thin layer of hyaline cartilage. An **interosseous fibro-cartilage** is interposed between the bony surfaces: it corresponds exactly in shape and intimately adheres to them. At each lateral border this fibro-cartilage enters into the formation of the second chondro-sternal articulation (fig. 282).

In consistence it varies, being in some cases uniform throughout, in others softer in the centre than at the circumference, and in others again an oval-shaped synovial cavity is found toward its anterior part. When such a cavity exists in the fibro-cartilage this joint has a remote resemblance to the diarthroses, and is classed, with the sacro-iliac joint and the symphysis pubis under similar conditions, as 'diarthro-amphiarthrosis.'

The periosteum passes uninterruptedly over the joint from one segment of the sternum to the other, forming a kind of capsular ligament [membrana sterni]. This capsule is strengthened, especially on its posterior aspect, by longitudinal ligamentous fibres as well as by the radiating and decussating fibres of the chondro-sternal ligaments.

In some instances the fibro-cartilage is replaced by short bundles of fibrous tissue which unite the cartilage-coated articular bony surfaces.

2. The Inferior Intersternal Articulation

Class.—*False Synchondrosis.*

The gladiolus is joined to the xiphoid cartilage by a thick investing membrane, by anterior and posterior longitudinal fibres, and by radiating fibres of the sixth and seventh chondro-sternal ligaments. The **costo-xiphoid ligament** also connects the xiphoid with the anterior surface of the sixth and seventh costal cartilages, and thus indirectly with the gladiolus; and some fine fibro-areolar tissue also connects the xiphoid with the back of the seventh costal cartilage.

The junction of the xiphoid with the sternum is on a level somewhat posterior to the junction of the seventh costal cartilage with the sternum. The union is a synchondrosis, each bone being covered by hyaline cartilage which is connected with the intervening fibro-cartilage plate.

(*b*) The Costo-chondral Joints

Class.—*Synarthrosis.*

The extremity of the costal cartilage is received into a cup-shaped depression at the end of the rib, which is somewhat larger than the cartilage. The two are joined together by the continuity of the investing membranes, the periosteum of the rib being continuous with the perichondrium of the cartilage.

(*c*) The Sterno-costal Articulations

Class.—*Diarthrosis.* **Subdivision**—*Ginglymus.*

These articulations are between the lateral borders of the sternum and the ends of the costal cartilages. The union of the first rib with the sternum is *synchondrodial,* and therefore forms an exception to the others. From the second to the seventh inclusive, the articulations have the following ligaments, which together form a complete capsule:—

Radiate (anterior) sterno-costal.	Superior sterno-costal.
Posterior sterno-costal.	Inferior sterno-costal.

The **radiate** (anterior) **sterno-costal ligament** (fig. 282) is a triangular band composed of strong fibres which cover the medial half-inch of the front of the costal cartilage, and radiate upward and downward upon the front of the sternum. Some of the fibres decussate across the middle line with fibres of the opposite ligament. At its upper and lower borders it is in contact with the superior and inferior ligaments respectively.

The **posterior sterno-costal ligament** consists of little more than a thickening of the fibrous envelopes of the bone and cartilage, the joint being completed behind by a continuity of perichondrium with periosteum.

The **superior** and **inferior ligaments** are strong, well-marked bands, which pass from the upper and lower borders respectively of the costal cartilage to the lateral edges of the sternum. The sixth and seventh cartilages are so close that the superior ligament of the seventh is blended with the inferior of the sixth rib.

Deeper than the fibres of these ligaments are short fibres passing from the margins of the sternal facets to the edges of the facets on the cartilages; they are most distinct in the front and lower part of the joint, and may encroach so much upon the synovial cavity as to reduce it to a very small size, or almost obliterate it. This occurs mostly in the case of the sixth and seventh joints, especially the latter.

The **interarticular ligament** (fig. 282) is by no means constant, but is usually present in the second joint on one, if not on both sides of the same subject. It consists of a strong transverse bundle of fibres passing from the ridge on the facet on the cartilage to the fibrous substance between the manubrium and body; sometimes the upper part of the synovial cavity is partially or entirely obliterated by short, fine, ligamentous fibres.

The **costo-xiphoid ligament** (fig. 282) is a strong flat band of fibres passing obliquely upward and laterally from the front surface of the xiphoid cartilage to the anterior surface of the sternal end of the seventh costal cartilage, and most frequently to that of the sixth also.

Synovial membranes.—The union of the first cartilage with the sternum being synchondrodial, it has no synovial membrane; the second has usually two, separated by the interarticular ligament. The rest usually have one synovial membrane, which may occasionally be subdivided into two (fig. 282).

The **arterial supply** is derived from perforating branches of the internal mammary; and the **nerves** come from the anterior branches of the intercostals.

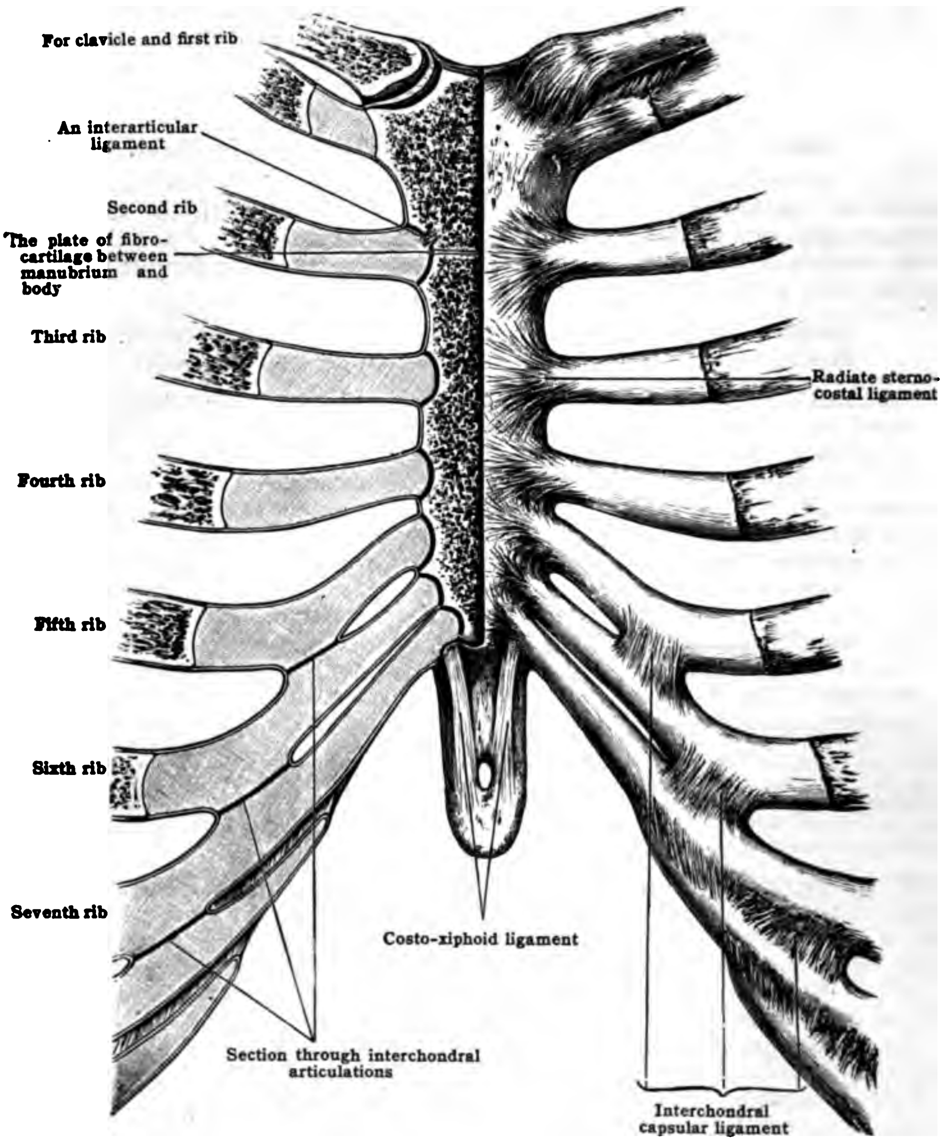
Movements.—Excepting the first, the chondro-sternal joints are ginglymoid, but the motion of which they are capable is very limited. It consists of a hinge-like action in two directions: first, there is a slight amount of elevation and depression which takes place round a transverse axis, and, secondly, there is some forward and backward movement round an obliquely vertical axis. In inspiration the cartilage is elevated, the lowest part of its articular facet is pressed into the sternal socket, and the sternum is thrust forward so that the upper

and front edges of the articular surfaces separate a little; in expiration the reverse movement takes place. Thus the two extremities of the costal arches move in their respective sockets in opposite directions.

This difference results necessarily from the fact that the costal arch moves upon the vertebral column, and, having been elevated, it in its turn raises the sternum by pushing it upward and forward.

The costo-xiphoid ligament tends to prevent the xiphoid cartilage from being drawn backward by the action of the diaphragm.

FIG. 282.—THE ARTICULATION AT THE FRONT OF THE THORAX.
(Left side, showing ligaments; right side, the synovial cavities.)



(*d*) THE INTERCHONDRAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

A little in front of the point where the costal cartilages bend upward toward the median line the sixth is united with the seventh, the seventh with the eighth, the eighth with the ninth, and the ninth with the tenth.

At this point each of the cartilages from the sixth to the ninth inclusive is deeper than elsewhere, owing to the projection downward from its lower edge of a broad blunt process, which comes into contact with the cartilage next below. Each of the apposed surfaces is smooth,

and they are connected at their margins by ligamentous tissue, which forms a complete **capsule** for the articulation, and is lined by a synovial membrane (fig. 282). The largest of these cavities is between the seventh and eighth; those between the eighth and ninth, and ninth and tenth, are smaller, and are not free to play upon each other in the whole of their extent, being held together by ligamentous tissue at their anterior margins. Sometimes this fibrous tissue completely obliterates the synovial cavity.

The **arteries** are derived from the musculo-phrenic, and the **nerves** from the intercostals.

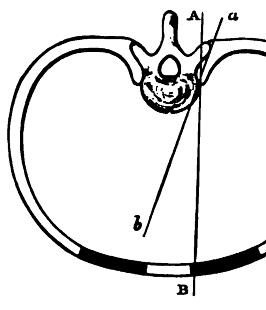
Movements.—By means of the costal cartilages and interchondral joints, strength with elasticity is given to the wall of the trunk at a part where the cartilages are the only firm structures in its composition; while a slight gliding movement is permitted between the costal cartilages themselves, which takes place round an axis corresponding to the long axis of the cartilages. By this means, the outward projection of the lower part of the thoracic wall is increased by deep inspiration.

MOVEMENTS OF THE THORAX AS A WHOLE

Before describing these movements as a whole, it must be premised that there are some few modifications in the movements of certain ribs resulting from their shape. Thus the first rib (and to a less extent the second also), which is flat on its upper and lower surfaces, revolves on a transverse axis drawn through the costo-vertebral and costo-transverse joints. During inspiration and expiration, the anterior extremities of the first pair of costal arches play up and down, the tubercles and the heads of the ribs acting in a hinge-like manner, the latter having also a slight screwing motion. By this movement the anterior ends of the costal arches are simply raised or depressed, and the sternum pushed a little forward; it may be likened to the movement of a pump-handle, as in fig. 283, *a*, *b*.

The movements of the other ribs, particularly in the mid-region of the thorax, are more complex, for, besides the elevation of the anterior extremities, the bodies and angles of the

Fig. 283.—Diagram of Axis of Rib-movement. (After Kirkes.)



ribs rise nearly as much as the extremities themselves. In this movement the tubercles of the ribs glide upward and backward in inspiration, and downward and forward in expiration; and the movement may be likened to that of a bucket handle, as in fig. 283, A, B.

During inspiration, the cavity of the thorax is increased in every direction. The **antero-posterior diameter** is increased by the thrusting forward of the sternum, caused by the elevation of the costal cartilages and fore part of the ribs, whereby they are brought to nearly the same level as the heads of the ribs. The **transverse diameter** is increased: (i) Behind, by the elevation of the middle part of the ribs; for when at rest the mid-part of the rib is on a lower level than either the costo-vertebral or chondro-sternal articulations. Owing to this obliquity the transverse diameter is increased when the rib is raised, and the increase is proportionate to the degree of obliquity. (ii) By the eversion of the lower border of the costal arch, which turns outward as the arch is raised. (iii) The transverse diameter is increased in front by the abduction of the anterior extremity of the rib at the same time as it is elevated and thrust forward.

The increase in the **vertical diameter** of the thorax is due to the elevation of the ribs, especially the upper ones, and the consequent widening of the intercostal spaces; but the chief increase in this direction is due to the descent of the diaphragm.

The greatest increase both in the antero-posterior and transverse diameters takes place where the ribs are longest, most oblique, and most curved at their angles, and where the bulkiest part of the lung is enclosed. This is on a level with the sixth, seventh, and eighth ribs.

At the lower part of the thorax, where the ribs have no relation to the lungs, and do not affect respiration directly by their movements, it is important that the costal arches should be thrown well outward in order to counteract the compression of the abdominal viscera by the contraction of the diaphragm.

By widening and steadying the lower part of the thorax during inspiration, the attachments of the muscular fibres of the diaphragm are widened, and their power increased.

Muscles which take part in the movements of inspiration.—(*a*) *Ordinary inspiration;* The scalenes, serratus posterior superior, the external and internal (?) intercostals, the diaphragm; the quadratus lumborum and serratus posterior inferior fixing the lower ribs, possibly the posterior fibres of the external oblique also helping to fix the lower ribs. (*b*) *Extraordinary inspiration:* The superior extremities are raised and fixed. The cervical part of the vertebral column and the head are extended, and in addition to the muscles of ordinary inspiration, the following

muscles also come into play: The pectoralis minor, the muscles which extend the head and the cervical part of the vertebral column, the sterno-mastoid and the supra- and infra-hyoid muscles, the lower fibres of the pectoralis major, some of the lower fibres of the serratus anterior, and, when the clavicle is fixed, the subclavius.

Expiration is produced by the elasticity of the lungs and the weight of the thorax, aided by the elastic reaction and contraction of the external and internal oblique muscles, the recti and pyramidales, the transversus abdominis, and the levatores ani and coccygei. In forcible expiration all muscles which depress the ribs and reduce the dimensions of the abdomen are thrown into action. The internal intercostals probably tend to contract the thorax, excepting the parts between the costal cartilages, which tend to expand the thorax.

THE ARTICULATIONS OF THE UPPER EXTREMITY

The articulations of the upper extremity are the following:—

1. The **sterno-costo-clavicular.**
2. The **scapulo-clavicular union.**
3. The **shoulder-joint.**
4. The **elbow-joint.**
5. The **radio-ulnar union.**
6. The **radio-carpal** or **wrist-joint.**
7. The **carpal joints.**
8. The **carpo-metacarpal joints.**
9. The **intermetacarpal joints.**
10. The **metacarpo-phalangeal joints.**
11. The **interphalangeal joints.**

1. THE STERNO-COSTO-CLAVICULAR ARTICULATION

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

At this joint the large medial end of the clavicle is united to the superior angle of the manubrium sterni, the first costal cartilage also assisting to support the clavicle. It is the only joint between the upper extremity and the trunk, and takes part in all the movements of the upper limb. Looking at the bones, one would say that they were in no way adapted to articulate with one another, and yet they assist in constructing a joint of security, strength, and importance. The bones are nowhere in actual contact, being completely separated by an articular disc. The interval between the joints of the two sides varies from one inch to an inch and a half (2.5–4 cm.). The ligaments of this joint are:—

(1) Articular capsule.	(3) Articular disc.
(2) Interclavicular.	(4) Costo-clavicular.

The **articular capsule** (fig. 284) consists of fibres, having varying directions and being of various strength and thickness, which completely surround the articulation, and are firmly connected with the edges of the interarticular fibro-cartilage.

The fibres at the back of the joint, sometimes styled the **posterior sterno-clavicular ligament,** are stronger than those in front or below, and consist of two sets: a superficial, passing upward and laterally from the manubrium sterni, to the projecting posterior edge of the end of the clavicle, a few being prolonged onward upon the posterior surface of the bone. A deeper set of fibres, especially thick and numerous below the clavicle, connect the interarticular cartilage with the clavicle and with the sternum, but do not extend from one bone to the other. The fibres in front, the **anterior sterno-clavicular ligament,** are well marked, but more lax and less tough than the posterior, and are overlaid by the tendinous sternal origin of the *sterno-mastoid,* the fibres of which run parallel to those of the ligament. They extend obliquely upward and laterally from the margin of the sternal facet to the anterior surface of the clavicle some little distance from the articular margin. The fibres which cover in the joint below are short, woolly, and consist more of fibro-areolar tissue than true fibrous tissue; they extend from the upper border of the first costal cartilage to the lower border of the clavicle just lateral to the articular margin, and fill up the gap between it and the costo-clavicular ligament. The superior portion consists of short tough fibres passing from the sternum to the articular disc; and of others welding the fibro-cartilage to the upper edge of the clavicle, only a few of them passing from the clavicle direct to the sternum.

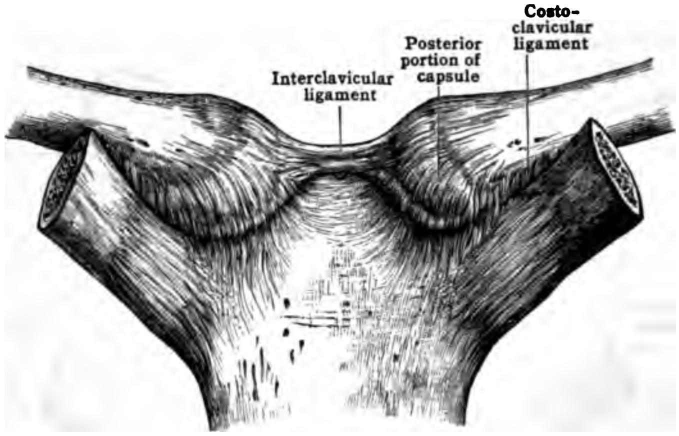
The **interclavicular ligament** (fig. 284) is a strong, concave band, materially *strengthening* the superior portion of the capsule. It is nearly a quarter of an

inch (6 mm.) deep with the concavity upward, its upper border tapering to a narrow, almost sharp edge. It is connected with the posterior superior angle of the sternal extremity of each clavicle, and with the fibres which weld the inter-articular cartilage to the clavicle; and then passes across from clavicle to clavicle along the posterior aspect of the upper border of the manubrium sterni. The lowest fibres are attached to the sternum, and join the posterior fibres of the capsule of each joint. In the middle line, between the ligament and the sternum, there is an aperture for the passage of a small artery and vein.

In addition to the interclavicular ligament Mr. Carwardine ("Journal of Anatomy and Physiology," vol. 7, new series, p. 232) has described a special band of the upper portion of the sterno-clavicular capsule which he proposes to name the 'suprasternal ligament.' It descends from the upper border of the sternal end of the clavicle to the upper border of the sternum, and is of special importance as it encloses the suprasternal bones, when these rudiments are present.

The **costo-clavicular** or rhomboid **ligament** (fig. 284) is a strong dense band, composed of fine fibres massed together into a membranous structure. It extends from the upper (medial) border of the first costal cartilage (and rib),

Fig. 284.—Posterior View of the Sterno-costo-clavicular Joint.



upward, backward, and distinctly laterally to the costal tuberosity on the under surface of the medial extremity of the clavicle, to which it is attached just lateral to the lower part of the capsule. Frequently some of the lateral fibres pass upward and medially behind the rest, and give the appearance of decussating. It is from half to three-quarters of an inch (1.5–2 cm.) broad.

The **articular disc** (fig. 285) is a flattened disc of nearly the same size and outline as the medial articular end of the clavicle, which it fairly accurately fits. It is attached above to the upper border of the posterior edge of the clavicle; and below to the cartilage of the first rib at its union with the sternum, where it assists in forming the socket for the clavicle. At its circumference it is connected with the articular capsule, and this connection is very strong behind, and still stronger above, where it is blended with the interclavicular ligament.

It is usually thinnest below, where it is connected with the costal cartilage. It varies in thickness in different parts, sometimes being thinner in the centre than at the circumference sometimes the reverse, and is occasionally perforated in the centre. It divides the joint into two compartments.

There are two **synovial membranes** (fig. 285); a lateral one, which is reflected from the clavicle and capsule over the lateral aspect of the disc and is looser than the medial one; the medial is reflected from the sternum over the medial side of the articular disc, costal cartilage, and capsule. Occasionally a communication takes place between them.

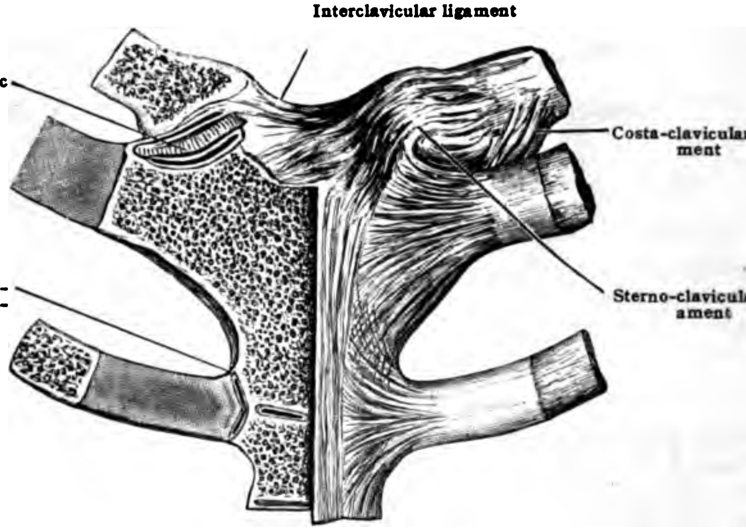
The **arterial supply** is derived from branches—(1) from the internal mammary; (2) from the superior thoracic branch of the axillary; (3) twigs of a muscular branch often arising from the subclavian artery pass over the interclavicular notch; (4) twigs of the transverse scapular (suprascapular) artery.

The **nerve-supply** is derived from the nerve to the *subclavius* and sternal descending branch of the cervical plexus.

Relations.—In front of the joint is the sternal head of the sterno-mastoid. Behind it are the sterno-hyoid and sterno-thyreoid muscles. Still further back, on the right side, are the innominate and internal mammary arteries, and, on the left side, the left common carotid, the left subclavian, and the internal mammary arteries. Above and behind, between the sterno-mastoid and sterno-hyoid muscles, the anterior jugular vein passes back and laterally toward the posterior triangle.

The **movements** permitted at this joint are various though limited, owing to the capsular ligament being moderately tense in every position of the clavicle. Motion takes place in nearly every direction—viz., upward, downward, forward, backward, and in a circumductory manner. The upward and downward motions occur between the clavicle and the articular disc; during elevation of the arm the upper edge of the clavicle with its attached articular disc is pressed into the sternal socket, and the lower edge glides away from the disc; during depression of the limb, the lower edge of the clavicle presses on to the disc, while the rest of the articular surface of the clavicle inclines laterally, bringing with it to a slight degree the upper edge of the articular disc. These movements occur on an antero-posterior axis drawn through the outer compartment of the joint. The forward and backward motions take place between the articular disc and sternum, the clavicle with the disc gliding backward upon the sternum when the shoulder is brought forward, and forward when the shoulder is forced backward; these movements occur round an axis drawn nearly vertically through the sternal socket.

FIG. 285.—ANTERIOR VIEW OF STERNO-COSTO-CLAVICULAR JOINT, WITH SECTION SHOWING CAVITIES OPENED ON THE RIGHT SIDE.



The articular disc serves materially to bind the bones together, and to prevent the media and upward displacements of the clavicle. It also forms an elastic buffer which tends to break shocks. The capsule, by being moderately tight, tends to limit movements in all directions, while the interclavicular ligament is a safeguard against upward displacement during depression of the arm. The costo-clavicular ligament prevents dislocation upward during elevation of the arm, and resists displacements backward.

Muscles which move the clavicle at the sterno-clavicular joint.—*Elevators.*—Trapezius, clavicular part of sterno-mastoid, levator scapulæ, omo-hyoid, rhomboids.

Depressors.—Subclavius, pectoralis minor, lower fibres of trapezius and serratus anterior (magnus). Depression is aided by the weight of the upper extremity.

Protractors.—Pectoralis major and minor. Serratus anterior (magnus).

Retractors.—Latissimus dorsi, trapezius.

2. THE SCAPULO-CLAVICULAR UNION

The scapula is connected with the clavicle by a synovial joint with its ligaments at the acromio-clavicular articulation; and also by a set of ligaments passing between the coracoid process and the clavicle. So that we have to consider—

(*a*) The **acromio-clavicular articulation.**
(*b*) The **coraco-clavicular ligaments.**
(*c*) The **proper scapular ligaments** are also best described in this section—viz., the **coraco-acromial** and **transverse.**

(*a*) The Acromio-clavicular Joint

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The acromio-clavicular joint is surrounded by an articular capsule and frequently contains an articular disc.

The **articular capsule** (figs. 287 and 290) completely surrounds the articular margins, and is composed of strong, coarse fibres arranged in parallel fasciculi, of fairly uniform thickness, which are attached to the borders as well as the surfaces of the bones. It is somewhat lax in all positions of the joint, so that the clavicle is not tightly braced to the acromion. The fibres extend three-quarters of an inch (2 cm.) along the clavicle posteriorly, but only a quarter of an inch (6 mm.) anteriorly. Superiorly, they are attached to an oblique line joining these two points, while inferiorly they reach to the ridge for the trapezoid ligament with which they blend.

At the acromion they extend half way across the upper and lower surfaces, but at the anterior and posterior limits of the joint they are attached close to the articular facet. The anterior fibres become blended with the insertion of the coraco-acromial ligament. The fibres are strengthened above by the aponeuroses of the *trapezius* and *deltoid* muscles; and all run from the acromion to the clavicle medially and backward.

The **articular disc** is occasionally present, but is usually imperfect, only occupying the upper part of the joint; it may completely divide the joint into two cavities, or be perforated in the centre. It is usually thicker at the edge than in the centre, and some of the fibres of the articular capsule are blended with its edges.

The **synovial membrane** lining the joint is occasionally either partially or entirely divided into two by the articular disc.

Relations.—Superiorly skin and fascia and the tendinous intersection between the deltoid and the trapezius. Inferiorly, the coraco-acromial ligament and supraspinatus. Anteriorly, part of the origin of the deltoid. Posteriorly, part of the insertion of the trapezius.

Movements.—A certain amount of gliding movement occurs at this joint, but the most important movement is a rotation of the scapula whereby the glenoid cavity is turned forward and upward, or downward. As these movements occur the inferior angle of the scapula moves forward as the glenoid cavity turns upward and the superior angle recedes.

The forward movement of the inferior angle is produced mainly by the inferior fibres of the serratus anterior (magnus), aided by the inferior fibres of the trapezius, and it is by this movement that the arm is raised above the level of the shoulder forward.

The reverse movement is produced mainly by the rhomboideus major aided by the latissimus dorsi.

(*b*) The Coraco-clavicular Union

The **coraco-clavicular ligament** (figs. 286, 287, and 290) consists of two parts, the conoid and the trapezoid ligaments.

The **conoid ligament** is the medial and posterior portion, and passes upward and laterally from the coracoid process to the clavicle.

It is a very strong and coarsely fasciculated band of triangular shape, the apex being fixed to the medial and posterior edge of the root of the coracoid process just in front of the scapular notch, some fibres joining the transverse ligament. Its base is at the clavicle, where it widens out, to be attached to the posterior edge of the inferior surface, as well as to the coracoid tubercle. It is easily separated from the trapezoid, without being absolutely distinct. A small bursa often exists between it and the coracoid process; medially, some of the fibres of the *subclavius* muscle are often attached to it.

The **trapezoid ligament** is the anterior and lateral portion of the coraco-clavicular ligament. It is a strong, flat, quadrilateral plane of closely woven fibres, the surfaces of which look upward and medially toward the clavicle, and downward and laterally over the upper surface of the coracoid process.

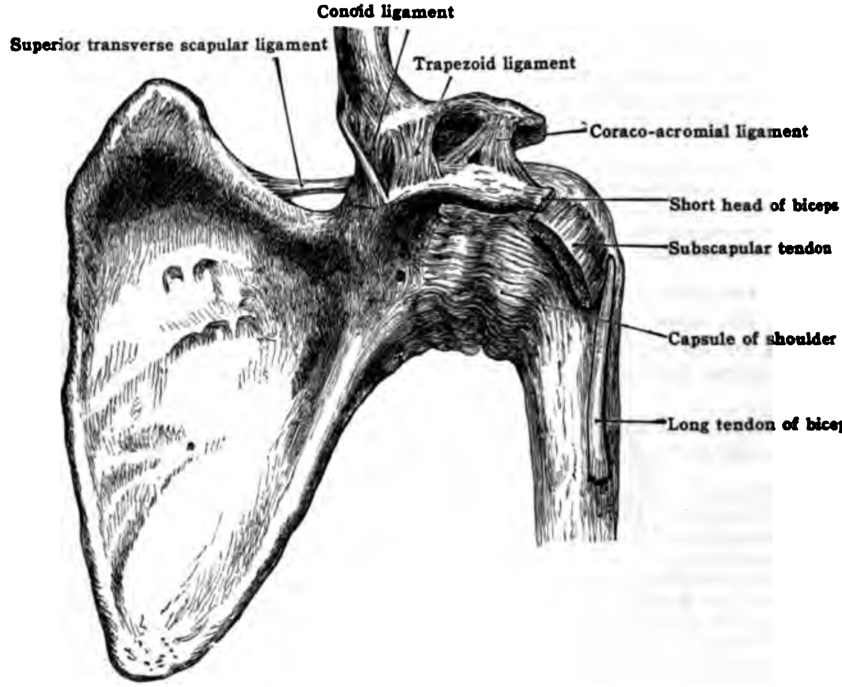
At the coracoid it is attached for about an inch (2.5 cm.) to a rough ridge which runs forward from the angle, along the anterior border of the process. At the clavicle it is attached to the oblique ridge which runs laterally and forward from the coracoid tubercle, reaching as far as, and blending with the inferior part of the acromio-clavicular ligament. Its anterior edge is free, and overlies the coraco-acromial ligament; the posterior edge is shorter than the anterior, and is in contact with the posterior and lateral portion of the conoid ligament.

The **arterial supply** is derived from the transverse scapular (suprascapular), acromial branches of the thoraco-acromial, and the anterior circumflex.

The **nerve-supply** is derived from the suprascapular and axillary (circumflex) nerves.

Movements.—In the movements of the shoulder girdle, the scapula moves upon the lateral end of the clavicle, and the clavicle, in turn, carried by the uniting ligaments, moves upon the sternum; so that the entire scapula moves in the arc of a circle whose centre is at the sterno-clavicular joint, and whose radius is the clavicle. The scapula, in moving upon the clavicle, also moves upon the thorax forward and backward, upward and downward, and also in a rotatory direction upon an axis drawn at right angles to the centre of the bone. Throughout these movements the inferior angle and base of the scapula are kept in contact with the ribs by the

FIG. 286.—ANTERIOR VIEW OF SHOULDER, SHOWING ALSO CORACO-CLAVICULAR AND CORACO-ACROMIAL LIGAMENTS.



latissimus dorsi, which straps down the former, and the *rhomboids* and *serratus anterior* (*magnus*), which brace down the latter. The glenoid cavity could not have preserved its obliquely forward direction had there been no acromio-clavicular joint, but would have shifted round a vertical axis, and thus the shoulder would have pointed medialward when the scapula was advanced, and lateralward when it was drawn backward. By means of the acromio-clavicular joint, the scapula can be forcibly advanced upon the thorax, the glenoid cavity all the time keeping its face duly forward. Thus the muscles of the shoulder and forearm can be with advantage combined, as, for example, in giving a direct blow. The acromio-clavicular joint also permits the lower angle of the scapula to be retained in contact with the chest wall during the rising and falling of the shoulder, the scapula turning in a hinge-like manner round the horizontal axis of the joint.

There are no actions in which the scapula moves on a fixed clavicle, or the clavicle on a fixed scapula; the two bones, bound together by their connecting ligament, must move in unison.

(*c*) THE PROPER SCAPULAR LIGAMENTS

There are three proper ligaments of the scapula, which pass between different portions of the bone, viz.—

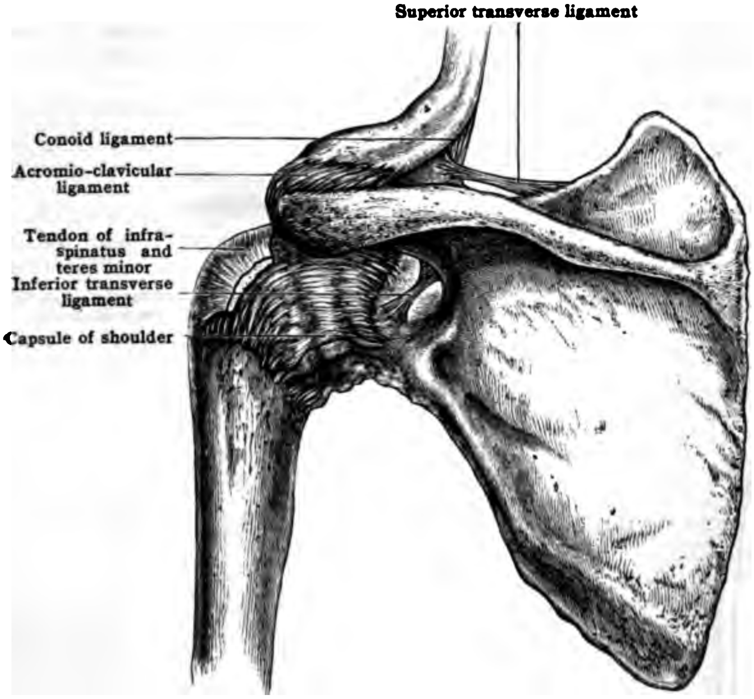
Coraco-acromial. Superior transverse.
Inferior transverse.

The **coraco-acromial ligament** (figs. 286 and 290) is a flat, triangular band with a broad base, attached to the lateral border of the coracoid process, and a blunt apex which is fixed to the tip of the acromion. It is made up of two broad marginal bands, and a smaller and thinner intervening portion. The **anterior band,** which arises from the anterior portion of the coracoid process, is the stronger, and some of its marginal fibres can often be traced into the short head of the biceps, which can then make tense this edge of the ligament. The **posterior band,** coming from the posterior part of the coracoid process, is also strong.

The intermediate part, of variable extent, is thin and membranous, containing but few ligamentous fibres; it is often incomplete near the coracoid process, leaving a small gap (fig. 286).

The superior surface of the ligament looks upward and a little forward, and is covered by the *deltoid* muscle; the inferior looks downward and a little backward, and is separated from the capsule of the shoulder-joint by a bursa and the tendons of the *supraspinatus* and *subscapularis* muscles. At the coracoid process it overlies the coraco-humeral ligament. It is barely one-third of an inch (8 mm.) above the capsule of the shoulder, and in the undissected state there is scarcely a quarter of an inch (6 mm.) interval. The anterior band projects over the centre of the head of the humerus, and is continued into a tough fascia under the deltoid; the posterior band is continuous with the fascia over the supraspinatus muscle. It binds the

FIG. 287.—POSTERIOR VIEW OF THE SHOULDER-JOINT, SHOWING ALSO THE ACROMIO-CLAVICULAR JOINT AND THE SPECIAL LIGAMENTS OF THE SCAPULA.



two processes firmly together, and so strengthens each; it holds the deltoid off the capsule of the shoulder, and protects the joint from slight injuries directed downward and backward against it.

The **superior transverse** (coracoid, or suprascapular) **ligament** (figs. 286, 287, and 288) is a small triangular band of fibrous tissue, the surfaces of which look forward and backward; and its edges, which are thin and sharp, are turned upward and downward. It continues the superior border of the scapula, bridging over the scapular notch.

It is broader medially, where it springs from the upper border of the scapula on its dorsal surface; and narrow laterally, where it is attached to the base of the coracoid process; some of its fibres are inserted under the edge of the trapezoid ligament, and others pass upward with the conoid to reach the clavicle. The *transverse scapular* (*suprascapular*) *artery* passes over it, and the *suprascapular nerve* beneath it. Medially, some fibres of the *omo-hyoid* muscle arise from it.

The **inferior transverse** (spino-glenoid) **ligament** (fig. 287) reaches from the lateral border of the spine of the scapula to the margin of the glenoid cavity, and so forms a foramen under which the *transverse scapular* (*suprascapular*) *vessels* and *suprascapular nerve* gain the infraspinous fossa. It is usually a weak membranous structure with but few ligamentous fibres.

3. THE SHOULDER-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Enarthrodia.*

The shoulder [articulatio humeri] is one of the most perfect and most movable

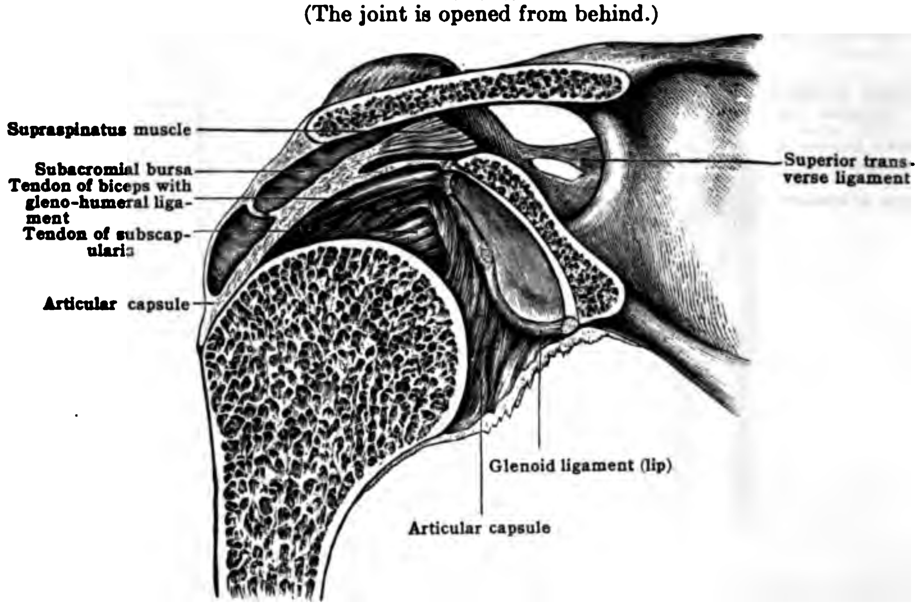
of joints, the large upper end of the humerus playing upon the shallow glenoid cavity. Like the hip, it is a ball-and-socket joint. It is retained in position much less by ligaments than by muscles, and, owing to the looseness of its capsule, as well as to all the other conditions of its construction and position, it is exceedingly liable to be displaced; on the other hand, it is sheltered from violence by the two projecting processes—the acromion and coracoid.

The ligaments of the shoulder-joint are:—

Articular capsule.	Coraco-humeral.
Gleno-humeral.	Glenoid.

The **articular capsule** (figs. 286, 287, and 288) is a loose sac, insufficient in itself to maintain the bones in contact. It consists of fairly distinct but not coarse fibres, closely woven together, and directed, some straight, others obliquely, between the two bones, a few circular ones being interwoven amongst them. At the scapula, it is fixed on the dorsal aspect to the prominent rough

FIG. 288.—VERTICAL SECTION THROUGH THE SHOULDER-JOINT TO SHOW THE GLENO-HUMERAL LIGAMENT.
(The joint is opened from behind.)



surface around the margin of the glenoid cavity, reaching as far as the neck of the bone. Superiorly, it is attached to the root of the coracoid process; anteriorly, to the ventral surface, at a variable distance from the articular margin, often reaching half an inch (12 mm.) upon the neck of the bone, and thus allowing the formation of a pouch; it may not, however, extend for more than a quarter of an inch (6 mm.) beyond the articular margin; inferiorly, it blends with the origin of the long head of the triceps. At the humerus, the superior half is fixed to the anatomical neck, sending a prolongation downward between the two tuberosities which attenuates as it descends, and covers the transverse humeral ligament. The lower half of the capsule descends upon the humerus further from the articular margin, some of the deeper fibres being reflected upward so as to be attached close to the articular edge, thus forming a kind of fibrous investment for the neck of the humerus. This ligament is more uniform in thickness than that of the hip.

Gleno-humeral bands of the capsule (figs. 288 and 289).—There are three accessory bands, known as the *superior*, *middle* and *inferior gleno-humeral bands*, which project toward the interior of the joint from the fore part of the capsule and are consequently best seen when the joint is opened from behind.

The **middle** band reaches from the anterior margin of the glenoid cavity along the lower border of the subscapularis tendon to the lower border of the lesser tuberosity, and the **inferior** band from the inferior part of the glenoid cavity to the inferior part of the neck of the humerus.

The **superior** band, known also as the **gleno-humeral ligament**, runs from the edge of the glenoid cavity at the root of the coracoid process, just medial to the origin of the long tendon of the biceps, and, passing laterally and downward at an acute angle to the tendon, for which it forms a slight groove or sulcus, is fixed to a depression, the fovea capitis humeri, above the lesser tuberosity of the humerus. It is a thin, ribbon-like band, of which the superior surface is attached to the capsule, while the inferior is free and turned toward the joint. In the fœtus it is often, and in the adult occasionally, quite free from the capsule, and may be as thick as the long tendon of the biceps (fig. 289).

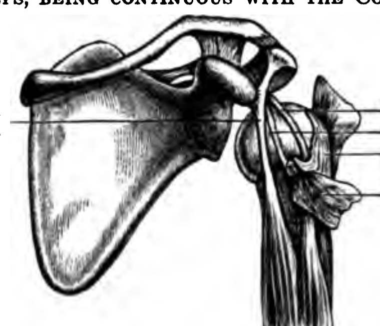
The tendons of the *supra-* and *infra-spinatus*, *teres minor*, and *subscapularis* muscles strengthen and support the capsule, especially near their points of insertion, and can be with difficulty dissected off from it. The long head of the *triceps* supports and strengthens the capsule below. The capsule also receives an upward slip from the *pectoralis major*. The *supraspinatus* often sends a slip into the capsule from its upper edge (fig. 288).

The **coraco-humeral ligament** (fig. 290) is a strong broad band, which is attached above to the lateral edge of the root and horizontal limb of the coracoid process nearly as far as the tip. From this origin it is directed backward along the line of the biceps tendon to blend with the capsule, and is inserted into the greater tuberosity of the humerus.

Seen from the back, it looks like an uninterrupted continuation of the capsule, while from the front it looks like a fan-shaped prolongation from it overlying the rest of the ligament. At its origin there is sometimes a bursa between it and the capsule.

The **glenoid ligament** or **lip** [labrum glenoidale] (figs. 288 and 292) is a narrow rim of dense fibro-cartilage, which surrounds the edge of the glenoid socket and deepens it. It is about a quarter of an inch (6 mm.) wide above and below, but less at its sides. Its peripheral edge is inseparably welded, near the bone, with

Fig. 289.—Fœtal Shoulder-joint, showing the Gleno-humeral Ligament, and also the Short Head of the Biceps, being continuous with the Coraco-acromial Ligament.



the articular capsule. Its structure is almost entirely fibrous, with but few cartilage cells intermixed. At the upper part of the fossa the **biceps tendon** is prolonged into the glenoid ligament, the tendon usually dividing and sending fibres right and left into the ligament, which may wind round nearly the whole circumference of the socket. It may, however, send fibres into one side only, usually into the lateral.

The **articular cartilage** covering the glenoid fossa is thicker at the circumference than in the centre, thus tending to deepen the cavity. It is usually thickest at the lower part of the fossa; over the head of the humerus the cartilage is thickest at and below the centre.

The **synovial membrane** lines the glenoid ligament, and is then reflected over the capsule as far as its attachment to the humerus, from which it ascends as far as the edge of the articular cartilage. The tendon of the *biceps* receives a long tubular sheath, which is continuous with the synovial membrane, both at its attached extremity and at the bicipital groove, but is free in the rest of its extent. The synovial cavity almost always communicates with the bursa under the *subscapularis*, and sometimes with one under the infraspinatus muscle.

It also sends a pouch-like prolongation beneath the coracoid process when the fibrous capsule is attached wide of the margin of the glenoid fossa. A few fringes are seen near the edge of the glenoid cavity, and there is often one which runs down the medial edge of the biceps tendon, extending slightly below it and making a slight groove for the tendon to lie in.

The **transverse humeral ligament** (fig. 290) is so closely connected with the capsule of the shoulder that, although it is a proper ligament of the humerus, it may well be described here. It is a strong band of fibrous tissue, which extends

FIG. 290.—LATERAL VIEW OF THE SHOULDER-JOINT, SHOWING THE CORACO-HUMERAL AND TRANSVERSE HUMERAL LIGAMENTS.

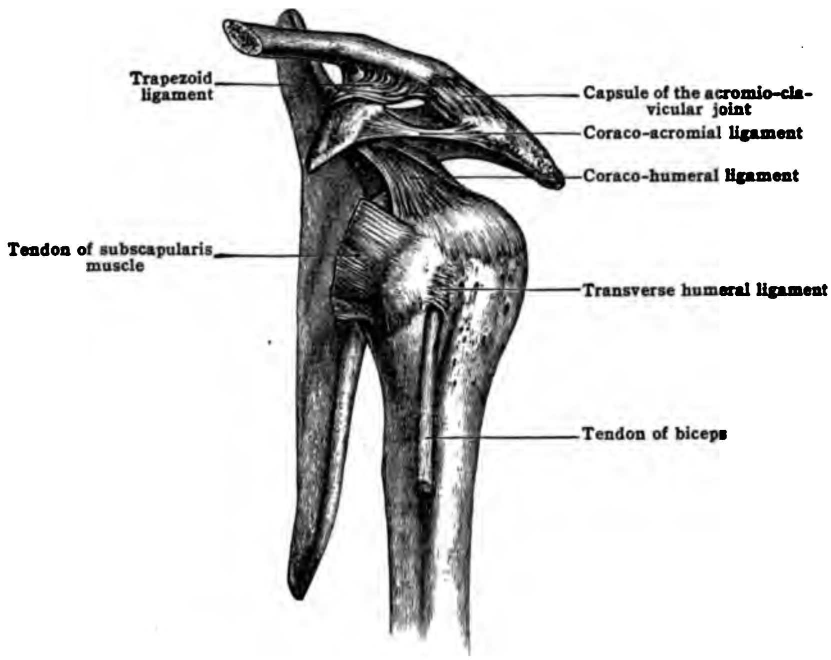
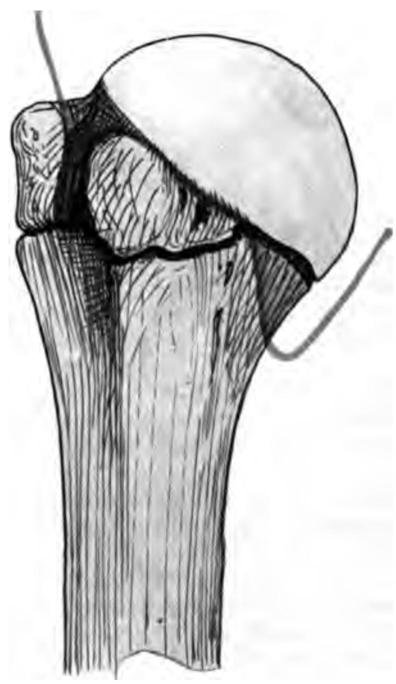


FIG. 291.—THE UPPER EXTREMITY OF THE HUMERUS, ANTERIOR VIEW, TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE SHOULDER-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



between the two tuberosities, roofing in the intertubercular (bicipital) **groove.** It is covered by a thin expansion of the capsule. It is limited to the **portion of the** *bone* above the line of the epiphysis.

Relations.—The following muscles are in contact with the capsule of the shoulder-joint. In front, the subscapularis; above, the supraspinatus; above and behind, the infraspinatus; behind, the teres minor; below, the long head of the triceps and the teres major. In the interval between the subscapularis and the supraspinatus the subacromial bursa is close to the capsule and occasionally its cavity communicates with the cavity of the joint.

The axillary (circumflex) nerve and posterior circumflex artery pass beneath the capsule in the interval between the long head of the triceps, the humerus, and the teres major. When the arm is abducted, the long head of the triceps and the teres major are drawn into closer relation with the capsule and help to prevent dislocation of the humerus.

The axillary vessels, the great nerves of the axilla, the short head of the biceps, and the coraco-brachialis are separated from the joint by the subscapularis, whilst the deltoid forms a kind of cap, which extends from the front to the back over the more immediate relations.

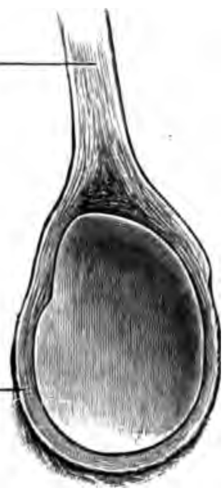
The arterial supply is derived from the transverse scapular (suprascapular), anterior and posterior circumflex, subscapular, circumflex scapular (dorsalis scapulæ), and a branch from the second portion of the axillary artery.

The nerve-supply is derived from the suprascapular, by branches in both fossæ; and from the axillary (circumflex) and subscapular nerves.

The movements of the shoulder-joint consist of flexion, extension, adduction, abduction, rotation and circumduction.

Flexion is the swinging forward, extension the swinging backward, of the humerus; abduction is the raising of the arm from, and adduction depression of the arm to, the side. In flexion and extension the head of the humerus moves upon the centre of the glenoid fossa round an

FIG. 292.—BICEPS TENDON, BIFURCATING AND BLENDING ON EACH SIDE WITH THE GLENOID LIGAMENT.



oblique line corresponding to the axis of the head and neck of the humerus, flexion being more free than extension, and in extreme flexion the scapula follows the head of the humerus, so as to keep the articular surfaces in apposition. In extension the scapula moves much less, if at all.

In abduction and adduction the scapula is fixed, and the humerus rolls up and down upon the glenoid fossa; during abduction the head descends until it projects beyond the lower edge of the glenoid cavity, and the greater tuberosity impinges against the arch of the acromion; during adduction, the head of the humerus ascends in its socket, the arm at length reaches the side, and the capsule is completely relaxed.

In circumduction, the humerus, by passing quickly through these movements, describes a cone, whose apex is at the shoulder-joint, and the base at the distal extremity of the bone or limb.

Rotation takes place round a vertical axis drawn through the extremities of the humerus from the centre of the head to the inner condyle; in rotation forward (that is, medialward) the head of the bone rolls back in the socket as the great tuberosity and shaft are turned forward; in rotation backward (that is, lateralward) the head of the bone glides forward, and the tuberosity and shaft of the humerus are turned backward, i. e., lateralward.

Great freedom of movement is permitted at the shoulder, and this is increased by the mobility of the scapula. Restraint is scarcely exercised at all upon the movements of the shoulder by the ligaments, but chiefly by the muscles of the joint.

In abduction, the lower part of the capsule is somewhat, and in extreme abduction considerably, tightened; and in rotation medialward and lateralward, the upper part of the capsule is made tense, as is also, in the latter movement, the coraco-humeral ligament.

The movements of abduction and extension have a most decided and definite resistance offered to them other than by muscles and ligaments, for the greater tuberosity of the humerus, by striking against the acromion process and coraco-acromial ligament, stops short any further advance of the bone in these directions, and thus abduction ceases altogether as soon as the arm

is raised to a right angle with the trunk, and extension shortly after the humerus passes the line of the trunk.

Further elevation of the arm beyond the right angle, in the abducted or extended position, is effected by the rotation of the scapula round its own axis by the action of the trapezius and serratus anterior muscles upon the sterno-clavicular and acromio-clavicular joints respectively.

The acromion and coracoid process, together with the coraco-acromial ligament, form an arch, which is separated by a bursa and the tendon of the *supraspinatus* from the capsule of the shoulder. Beneath this arch the movements of the joint take place, and against it the head and tuberosities are pressed when the weight of the trunk is supported by the arms; the greater tuberosity and the upper part of the shaft impinge upon it when abduction and extension are carried to their fullest extent.

No description of the shoulder-joint would be complete without a short notice of the peculiar relation which the biceps tendon bears to the joint. It passes over the head of the humerus a little to the medial side of its summit, and lies free within the capsule, surrounded only by a tubular process of synovial membrane. It is flat, with the surfaces looking upward and downward, until it reaches the intertubercular (bicipital) groove, when it assumes a rounded form. It strengthens the articulation along the same course as the coraco-humeral ligament, and tends to prevent the head of the humerus from being pulled upward too forcibly against the inferior surface of the acromion. It also serves the purpose of a ligament by steadying the head of the humerus in various movements of the arm and forearm, and to this end is let into a groove at the upper end of the bone, from which it cannot escape on account of the abutting tuberosities and the strong transverse humeral ligament which binds it down. Further, it acts like the four shoulder muscles which pass over the capsule, to keep the head of the humerus against the glenoid socket; and, moreover, it resists the tendency of the *pectoralis major* and *latissimus dorsi* muscles, in certain actions when the arm is away from the side of the body, to pull the head of the humerus below the lower edge of the cavity.

Muscles which act upon the shoulder-joint.—*Flexors or protractors.*—Deltoid (anterior fibres), pectoralis major (clavicular fibres), coraco-brachialis, biceps (short head), subscapularis (upper fibres).

Extensors or retractors.—Latissimus dorsi, deltoid (posterior fibres), teres major, teres minor, infraspinatus (lower fibres).

Abductors.—Deltoid, supraspinatus, biceps (long head).

Adductors.—Pectoralis major, latissimus dorsi, subscapularis, infraspinatus, teres major, teres minor, coraco-brachialis, biceps (short head), triceps (lower head).

Medial rotators.—Pectoralis major, latissimus dorsi, teres major, subscapularis, deltoid (anterior fibres).

Lateral rotators.—Deltoid (posterior fibres), infraspinatus, teres minor.

Circumductors.—The above groups acting consecutively.

4. THE ELBOW-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The elbow [articulatio cubiti] is a complete hinge, and, unlike the knee, depends for its security and strength upon the configuration of its bones rather than on the number, strength, or arrangement of its ligaments. The bones composing it are the lower end of the humerus above, and the upper ends of the radius and ulna below; the articular surface of the humerus being received partly within the semilunar notch (great sigmoid cavity) of the ulna, and partly upon the cup-shaped area (fovea) of the radial head. The ligaments form one large and capacious capsule [capsula articularis], which, by blending with the annular ligament, and then passing on to be attached to the neck of the radius, embraces the elbow and the superior radio-ulnar joints, uniting them into one. Laterally, it is considerably strengthened by superadded fibres arising from the epicondyles of the humerus and inseparably connected with the capsule. For convenience of description it will be spoken of as consisting of four portions:—

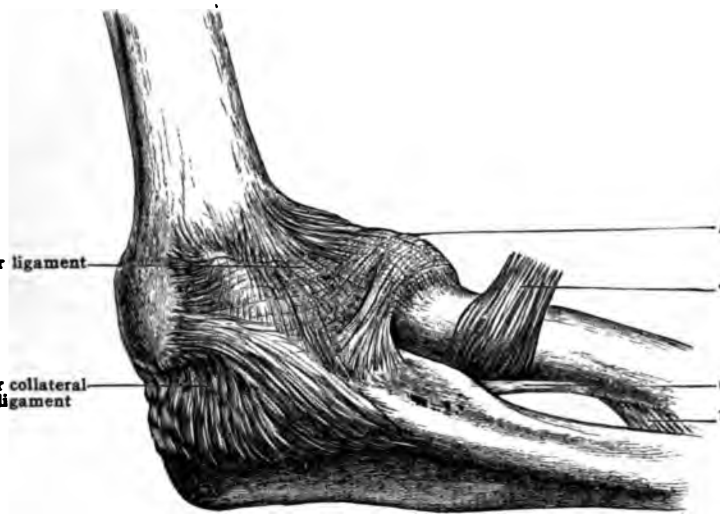
Anterior.	Medial.
Posterior.	Lateral.

The **anterior portion** (fig. 293) is attached to the front of the humerus above the articular surface and coronoid fossa, in an inverted **V**-shaped manner, to two very faintly marked ridges which start from the front of the medial and lateral epicondyles, and meet a variable distance above the coronoid fossa. Below, it is fixed, just beyond the articular margin, to the front of the coronoid process and it is intimately blended with the front of the annular ligament, a few fibres passing on to the neck of the radius.

It varies in strength and thickness, being sometimes so thin as barely to cover the synovial membrane; at others, thick and strong, and formed of coarse decussating fibres, the majority of which descend from the medial side laterally to the radius.

The **posterior portion** (fig. 294), thin and membranous, is attached superiorly to the humerus, in much the same inverted V-shaped way as the anterior; ascending from the medial epicondyle, along the medial side of the olecranon fossa nearly to the top; then, crossing the bottom of the fossa, it descends on the lateral side, skirting the lateral margin of the trochlear surface, and turns laterally along the posterior edge of the capitulum. Inferiorly, it is attached to a slight groove

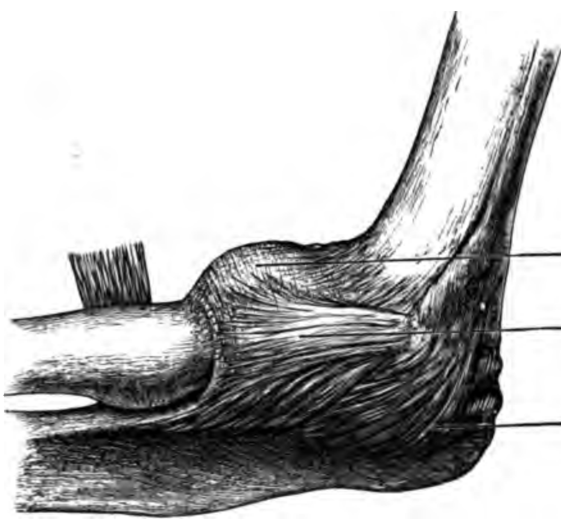
Fig. 293.—Medial View of the Elbow-joint.



along the superior and lateral surfaces of the olecranon, and the rough surface of the ulna just beyond the radial notch, and to the annular ligament, a few fibres passing on to the neck of the radius.

It is composed of decussating fibres, most of which pass vertically or obliquely downward, a few taking a transverse course at the summit of the olecranon fossa where the ligament is usually thinnest.

Fig. 294.—Lateral View of the Elbow-joint.

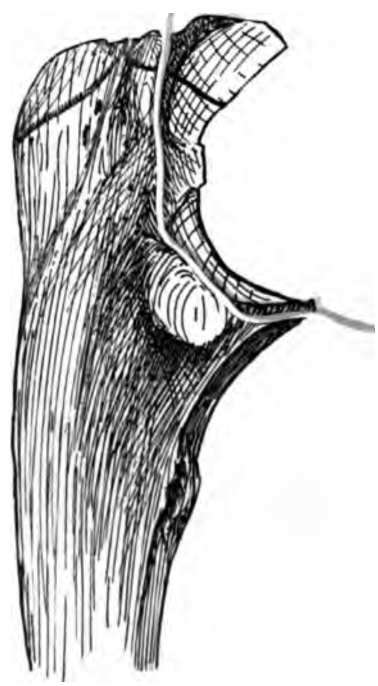


The **medial portion,** the **ulnar collateral ligament** (fig. 293), is thicker, stronger, and denser than either the anterior or posterior portions. It is triangular in form, its apex being attached to the anterior and under aspect of the medial epicondyle, and to the condyloid edge of the groove between the trochlea and the condyle. The fibres radiate downward from this attachment, the anterior passing forward to be fixed to the rough overhanging medial edge of the coronoid

process; the middle descend less obliquely to a ridge running between the coronoid and olecranon processes, while the posterior pass obliquely backward to the medial edge of the olecranon just beyond the articular margin.

FIG. 295.—LOWER EXTREMITY OF THE HUMERUS, TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE ELBOW-JOINT (IN RED) TO THE EPIPHYSIAL LINES.

FIG. 296.—THE UPPER EXTREMITY OF THE ULNA, TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE ELBOW-JOINT (IN RED) TO THE EPIPHYSIAL LINES.



An oblique band (the oblique ligament of Sir Astley Cooper) connects the margin of the olecranon process with the margin of the coronoid process. It lies superficial to the posterior fibres of the ulnar collateral ligament. The anterior fibres are the thickest, strongest, and most pronounced.

The **lateral portion,** the **radial collateral ligament** (fig. 294), is attached above to the lower part of the lateral epicondyle, and from this the fibres radiate to their attachment into the lateral side of the annular ligament, a few fibres being prolonged to reach the neck of the radius. The anterior fibres reach further forward than the posterior do behind. It is strong and well-marked, but less so than the medial portion.

The **synovial membrane** lines the whole of the capsule, and extends into the superior radio-ulnar joint, lining the annular ligament.

Outside the synovial membrane, but inside the capsule, are often seen some pads of fatty tissue; one is situated on the medial side at the base of the olecranon, another is seen on the lateral side projecting into the cavity between the radius and ulna; this latter, with a fold of synovial membrane opposite the front of the lateral lip of the trochlea, suggests the division of the joint into two parts—one medially for the ulna, and another laterally for the radius. There are also pads of fatty tissue at the bottom of the olecranon and coronoid fossæ, and at the tip of the olecranon process.

The **arterial supply** is derived from each of the vessels forming the free anastomosis around the elbow, and there is also a special branch to the front and lateral side of the joint, from the brachial artery, and the arterial branch to the *brachialis* also feeds the front of the joint.

The **nerve-supply** comes chiefly from the musculo-cutaneous; the ulnar, median, and radial (musculo-spiral) also give filaments to the joint.

Relations.—In front of the joint, and in immediate relation with the capsule, are the brachialis, the superficial and deep branches of the radial (musculo-spiral) nerve, the radial recurrent artery, and the brachio-radialis. The brachial artery, the median nerve, and the pronator teres are separated from the capsule by the brachialis. Directly behind the capsule are the triceps, the anconeus, and the posterior interosseous recurrent artery. On the medial side are the ulnar nerve, the superior ulnar collateral (posterior ulnar recurrent) artery, and the upper parts of the flexor carpi ulnaris and flexor digitorum sublimis. On the lateral side lie the extensor carpi radialis longus and the upper part of the common tendon of origin of the superficial extensors of the wrist and fingers.

The **movements** permitted at the elbow are those of a true hinge joint, viz., flexion and extension. These movements are oblique, so that the forearm is inclined medially in flexion, and laterally in extension; they are limited by the contact respectively of the coronoid and olecranon processes of the ulna with their corresponding fossæ on the humerus, and their extent is determined by the relative proportion between the length of the processes and depth of the fossæ which receive them, rather than by the tension of the ligaments, or the bulk of the soft parts over them. The anterior and posterior portions of the capsule, together with the corresponding portions of the collateral ligament, are not put on the stretch during flexion and extension; but, although they may assist in checking the velocity, and thus prevent undue force of impact, they do not control or determine the extent of these movements. The limit of extension is reached when the ulna is nearly in a straight line with the humerus; and the limit of flexion when the ulna describes an angle of from 30° to 40° with the humerus.

The obliquity of these movements is due to the lateral inclination of the upper and back part of the trochlear surface, and the greater prominence of the medial lip of the trochlea below; thus the plane of motion is directed from behind forward and medially, and carries the hand toward the middle third of the clavicle. The obliquity of the joint, the twist of the shaft of the humerus, and the backward direction of its head, all tend to bring the hand toward the midline of the body, under the immediate observation of the eye, whether for defence, employment, or nourishment. This is in striking contrast to the lower limb, where the direction of the foot diverges from the median axis of the trunk, thus preventing awkwardness in locomotion. In flexion and extension, the cup-like depression of the radial head glides upon the capitulum, and the medial margin of the radial head travels in the groove between the capitulum and the trochlea. This allows the radius to rotate upon the humerus while following the ulna in all its movements. In full extension and supination, the head of the radius is barely in contact with the inferior surface of the capitulum, and projects so much backward that its posterior margin can be felt as a prominence at the back of the elbow. In full flexion the anterior edge of the radial head is received into, and checked against, the depression above the capitulum; while in mid-flexion the cup-like depression is fairly received upon the capitulum, and in this position, the radius being more completely steadied by the humerus than in any other, pronation and supination take place most perfectly.

Muscles which act upon the elbow-joint.—*Flexors.*—Brachialis, biceps, brachio-radialis, pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis, flexor carpi ulnaris.

Extensors.—Triceps, anconeus, and the muscles which spring from the lateral epicondyle

5. THE UNION OF THE RADIUS WITH THE ULNA

The radius is firmly united to the ulna by two joints, and an intermediate fibrous union, viz.:—

(*a*) **The superior radio-ulnar**—whereat the head of the radius *rotates* within the radial notch and annular ligament.

(*b*) The **union of the shafts**—the **mid radio-ulnar union.**

(*c*) The **inferior radio-ulnar**—whereat the lower end of the radius *rolls round* the head of the ulna.

(a) The Superior Radio-ulnar Joint

Class.—*Diarthrosis.* **Subdivision.**—*Trochoides.*

The bones which enter into this joint (which is often included with the elbow-joint) are, the ulna by its radial notch and the radius by the smooth vertical border or rim on its head. There is but one ligament special to the joint, viz.:—

Annular.

The **annular ligament** consists of bands of strong fibres, somewhat thicker than the capsule of the elbow-joint, which encircle the head of the radius, retaining it against the side of the ulna. The bulk of these fibres forms about three-fourths of a circle, and they are attached to the anterior and posterior margins of the radial notch; some few are continued round below the radial notch, and form a complete ligamentous circle.

The ligament is inseparably connected along its upper edge and lateral (i. e., its non-articular) surface with the anterior, posterior, and lateral portions of the capsule of the elbow, a few of the fibres of these portions, especially of the lateral, descending to be attached to the neck of the radius. The lower part of the articulation is covered in anteriorly, posteriorly, and laterally by a thin independent membranous layer, which passes from the lower edge of the annular ligament to the neck of the radius, strengthened on the lateral side by those fibres passing down from the capsule. They are loose enough to allow the bone to rotate upon its

Fig. 297.—Annular Ligament.
(The head of the radius removed to show the membranous connection of this ligament with the radius.)

own axis (fig. 297). Medially and below the cavity is closed in by a loose membrane, the ligamentum quadratum, which passes from the lower border of the radial notch to the neck of the radius.

The **synovial membrane** is the same as that of the elbow-joint, and, after lining the annular ligament, passes on to the neck of the radius, and thence up to the lower margin of the articular cartilage.

The **arterial and nerve-supply** are the same as those to the lateral part of the elbow-joint.
Relations.—Behind lies the anconeus and in front the lateral border of the brachialis.

(b) The Mid Radio-ulnar Union

Class.—*Synarthrosis.* **Subdivision.**—*Syndesmosis.*

There are two interosseous ligaments which pass betweeen the shafts of the bones and unite them firmly together, viz.:—

Oblique cord. Interosseous membrane.

The **oblique cord** [chorda obliqua] (figs. 293 and 298) is a fairly strong, narrow *band, which passes* from the lower end of the rough lateral border of the coronoid

rocess, downward and laterally to be attached to the posterior edge of the ›wer end of the tuberosity of the radius and the vertical ridge running from it ›the medial border of the bone.

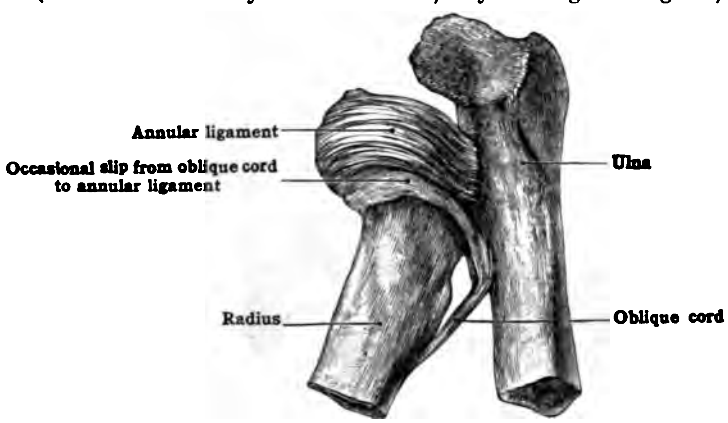
Some of its fibres blend with the fibres of insertion of the biceps tendon; behind, it is in ose contact with the *supinator;* below, a thin membrane passes off from it to the upper edge : the interosseous membrane; the posterior interosseous vessels pass in the space between it ıd the interosseous membrane; occasionally a slip is continued into the annular ligament of the ıperior radio-ulnar articulation (see fig. 298).

The **interosseous membrane** (fig. 293) is attached to the ulna at the lowest art of the ridge in front of the depression for the supinator, and along the whole ıngth of the interosseous border as far as the inferior radio-ulnar articulation, pproaching the front of the bone in the lower part of its attachment. To the ıdius it is attached along the interosseous border, from an inch (2.5 cm.) below ıe tuberosity to the ulnar notch for the lower end of the ulna.

It is strongest and broadest in the centre, where the fibres are dense and closely packed; is also well marked beneath the *pronator quadratus,* and thickens considerably at the lower end, ırming a strong band of union between the two bones. Its fibres pass chiefly downward ıd medially, from the radius to the ulna, though some take the opposite direction; at the lower ıd some are transverse. On the posterior surface are one or two bands, which pass downward ıd laterally from the ulna to the radius, and frequently there is a strong bundle as large as the

IG. 298.—UPPER PORTIONS OF LEFT ULNA AND RADIUS, TO SHOW AN OCCASIONAL SLIP FROM THE OBLIQUE CORD TO THE LOWER PART OF THE ANNULAR LIGAMENT. This condition is present in the spider monkey (*Ateles*), which has no external thumb but only rudimentary bones of one.

(From a dissection by Mr. W. Pearson, Royal College of Surgeons, England.)



›lique cord; this, which may be called the **inferior oblique ligament** (fig. 303), stretches from ıe ulna, an inch and a half above its lower extremity, downward and laterally to the ridge ›ove and behind the ulnar notch of the radius.

At its attachment to the bones, the interosseous membrane blends with the periosteum. s upper border is connected with the oblique cord by a thin membrane, which is pierced by ıe posterior interosseous vessels; and the lower border, which stretches across between the two ›nes just above the inferior radio-ulnar articulation, assists in completing the capsule of that int. Its anterior surface is in relation with the *flexor digitorum profundus and flexor pollicis ngus* in the upper three-quarters, the lower fourth being in relation with the *pronator quadratus.* he anterior interosseous vessels and nerve descend along the middle of the membrane, the tery being bound down to it. About an inch from the lower end it is pierced by the anterior terosseous artery. The posterior surface is in relation with the *supinator, abductor pollicis ngus* (*extensor ossis metacarpi pollicis*), *extensor pollicis longus* and *brevis,* and the *extensor dicis proprius;* at its lower part, also with the posterior branch of the anterior interosseous tery, and the deep branch of the radial nerve (posterior interosseous).

(c) THE INFERIOR RADIO-ULNAR JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Trochoides.*

This is, in one respect, the reverse of the superior; for the radius, instead of :esenting a circular head to rotate upon the facet on the ulna, presents a concave ‹cet which rolls round the ulna. The articulation may be said to consist of two

parts at right angles to each other; one between the radius and ulna, and the other between the ulna and the articular disc (triangular fibro-cartilage).

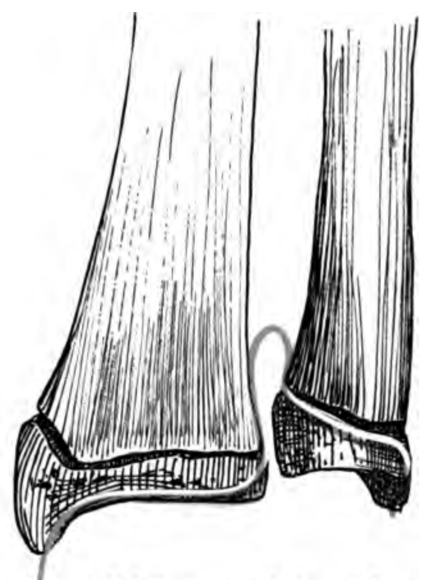
The ligaments are:—

Anterior radio-ulnar. Posterior radio-ulnar.
Articular disc.

The **articular disc** (triangular fibro-cartilage) (figs. 303 and 304) assists the radius in forming an arch under which is received the first row of carpal bones. Its base is attached to the margin of the radius, separating the ulnar notch from the articular surface for the carpus, while its apex is fixed to the fossa at the base of the styloid process of the ulna. It gradually and uniformly diminishes in width from base to apex, becoming rounded where it is fixed to the ulna; it is joined by fibres of the ulnar collateral ligament of the wrist.

The articular disc is about three-eighths of an inch (1 cm.) wide, and the same from base to apex; thicker at the circumference than in the centre; smooth and concave above to adapt

FIG. 299.—LOWER EXTREMITIES OF THE RADIUS AND ULNA TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE WRIST JOINT (in red) TO THE EPIPHYSIAL LINES. Note the upward extension of the membrana sacciformis.



itself to the ulna, and smooth and slightly concave below to fit over the triquetral bone. Its anterior and posterior borders are united to the anterior and posterior radio-ulnar and radio-carpal ligaments. It is the most important structure in the inferior radio-carpal articulation, as it is a very firm bond of union between the lower ends of the bones, and serves to limit their movements upon one another more than any other structure in either the upper or lower radio-ulnar joints. Its structure is fibrous at the circumference, while in the centre there is a preponderance of cells. It differs from all other fibro-cartilages in entering into two distinct articulations; and separates entirely the synovial membrane of the radio-ulnar joint from that of the wrist.

The lower end of the **interosseous membrane** extends between the ulna and radius immediately above their points of contact. Transverse fibres between the two bones form a sort of arch above the concave articular facet of the radius, and, joining the anterior and posterior radio-ulnar ligaments, complete the **articular capsule** of the inferior radio-ulnar joint. The ligaments represent merely thickenings of the capsule.

The **anterior radio-ulnar ligament** (fig. 300) is attached by one end to the anterior edge of the ulnar notch of the radius, and by the other to the rough bone above the articular surface of the ulna as far medially as the notch, as well as into the anterior margin of the triangular cartilage from base to apex.

The **posterior radio-ulnar ligament** (fig. 301) is similarly attached to the posterior margin of the ulnar notch at one end, and at the other to the rough bone above the articular surface of the extremity of the ulna as far medially as the groove for the ***extensor carpi ulnaris***, with the sheath of which it is connected, as well as into the whole length of the posterior margin of the articular disc. Both the radio-ulnar ligaments consist of thin, almost scattered, fibres.

The **synovial membrane,** sometimes called **the membrana sacciformis,** is large and loose in proportion to the size of the joint. It is not only interposed between the radial and ulnar articular surfaces, but lines the terminal articular surface of the ulna and the upper surface of the articular disc.

The **arterial supply** is derived from the volar interosseous artery and branches of the volar carpal rete.

The **nerve-supply** comes from the volar interosseous of the median, and the deep branch of the radial (posterior interosseous).

Relations.—Behind lies the tendon of the extensor digiti quinti proprius and in front the flexor digitorum profundus.

The movements of the radius.—The upper end of the radius rotates upon an axis drawn through its own head and neck within the collar formed by the radial notch and the annular ligament, while the lower end, retained in position by the articular disc, rolls round the head of the ulna. This rotation is called *pronation*, when the radius from a position nearly parallel to the ulna turns medialward so as to lie obliquely across it; and *supination*, when the radius turns back again, so as to uncross and lie nearly parallel with the ulna. In these movements the radius carries with it the hand, which rotates on an axis passing along the ulnar side of the hand; thus, the hand when pronated lies with its dorsum upward, as in playing the piano, while when supinated, the palm lies upward—the attitude of a beggar asking alms. Ward thus expresses the relations of the two extremities of the radius in pronation and supination: 'The head of the radius is so disposed in relation to the sigmoid cavity (ulnar notch) at the lower end that the axis of the former if prolonged falls upon the centre of the circle of which the latter is a segment;' the axis thus passes through the lower end of the ulna at a point at which the articular disc is attached, and if prolonged further, passes through the ring finger. Thus the radius describes, in rotating, a blunt-pointed cone whose apex is the centre of the radial head, and whose base is at the wrist; partial rotation of the bone being unaccompanied by any hinge-like or antero-posterior motion of its head, and pronation and supination occurring without disturbance to the parallelism of the bones at the superior radio-ulnar joint. Associated with this rotation in the ordinary way, there is some rotation of the humero-ulnar shaft, which causes lateral shifting of the hand from side to side; thus, with pronation there is some abduction, and with supination some adduction combined, so that the hand can keep on the same superficies in both pronation and supination. The power of supination in man is much greater than pronation, owing to the immense power and leverage obtained by the curve of the radius, and by the attachment of the biceps tendon to the back of the tuberosity. For this reason all our screw-driving and boring tools are made to be used by supination movements.

In the undissected state, the amount of rotation it is possible to obtain is about 135°, so that neither the palm nor the fore part of the lower end of the radius can be turned completely in opposite directions; yet in the living subject this amount can be greatly increased by rotation of the humero-ulnar shaft at the shoulder-joint.

Pronation is checked in the living subject by (a) the posterior inferior radio-ulnar ligament, which is strengthened by the connection of the sheath of the extensor tendons with it; (b) the lowermost fibres of the interosseous membrane; (c) the back part of the ulnar collateral and adjacent fibres of the posterior ligament of the wrist, and (d) the meeting of the soft parts on the front of the forearm.

Supination is checked mainly (a) by the medial ulnar collateral ligaments of the wrist, but partly also by (b) the oblique cord; (c) the anterior inferior radio-ulnar ligament, and (d) the lowest fibres of the interosseous membrane.

The interosseous membrane serves, from the direction of its fibres downward and medially from the radius to the ulna, to transmit the weight of the body from the ulna to the radius in the extended position of the elbow, as in pushing forward with the arms extended, or in supporting one's own weight on the hands, the ulna being in intimate contact with the humerus, but not at all with the carpus; while the area of contact of the radius with the humerus is small, and that of the radius with the carpus large. Hence the weight transmitted by the ulna is communicated to the radius by the tightening of the interosseous membrane. Conversely, in falls upon the hand with the arm extended, the interosseous membrane acts as a sling to break the violence of the shock, and prevents the whole force of the impact from expending itself directly upon the capitulum.

Muscles which act upon the radio-ulnar joints.—*Pronators.*—Pronator teres, pronator quadratus, flexor carpi radialis, palmaris longus.

Supinators.—Biceps, supinator, extensor pollicis longus.

The brachio-radialis is chiefly a flexor of the elbow-joint, but it takes part in the initiation of the movement of supination when the hand is fully pronated and of pronation when the hand is fully supinated.

6. THE RADIO-CARPAL OR WRIST-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

The wrist-joint is formed by the union of the radius and articular disc above, articulating with the navicular, lunate, and triquetral bones below; the ulna being excluded by the intervention of the articular disc. The radius and disc together present a smooth surface, slightly concave both from before backward, and from side to side, whilst the three bones of the carpus present a smooth,

ıvex surface, made uniformly even by the interosseous ligame
em together.

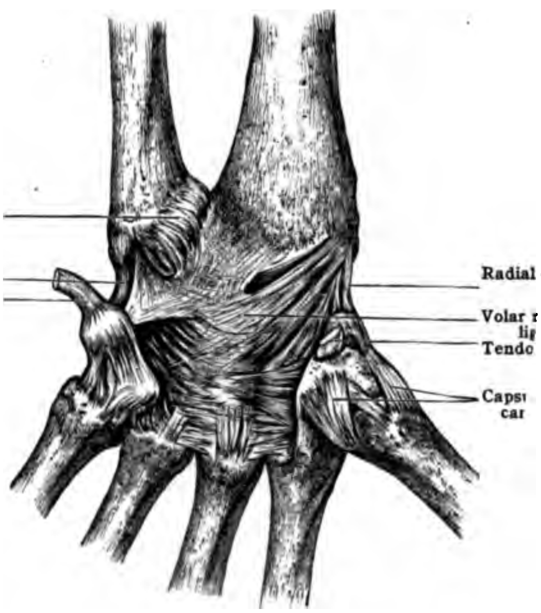
The capsule of the wrist-joint has been usually described as fou
ıents, and it will be convenient for the sake of a complete descri
ıis method; but it must be understood that these four portions
round the joint, extending from styloid process to styloid proc
ıspects.

The four portions are:—

Volar radio-carpal. Ulnar collatera
Dorsal radio-carpal. Radial collater

The **volar** (or anterior) **radio-carpal** (fig. 300) is a thick stron
tached superiorly to the radius immediately above the anterior
terminal articular facet, to the curved ridge at the root of the st
the radius, and to the anterior margin of the articular disc, blen
fibres of the capsule of the inferior radio-ulnar joint. It passes
in a medial direction to be attached to both rows of carpal bones
second, and to the volar intercarpal ligament.

FIG. 300.—ANTERIOR VIEW OF WRIST.



The strongest and most oblique fibres arise from the root of the stylo
and pass obliquely over the navicular, with which only a few fibres are c
into the lunate, capitate, and triquetral bones. Another set, less oblique
of the facet for the lunate to be attached to the adjacent parts of the ca
quetral bones. Between the two sets of fibres, small vessels pass into

The **dorsal** (or posterior) **radio-carpal ligament** (fig. 3C
to the dorsal edge of the lower end of the radius, the back
and the posterior margin of the fibro-cartilage. It passe
medial direction to be connected with the first row of th
with the lunate and triquetral, and the dorsal interc
ligament is thin and membranous.

It is strengthened by (i) strong fibres passing from the back
they are blended with the posterior inferior radio-ulnar ligament, an
just behind the ulnar notch, to the triquetral bone; (ii) from the ridg
pollicis longus to the back of the lunate and triquetral bones; and
radial extensors to the back of the navicular and lunate. It is in re
by, the extensor tendons which pass over it.

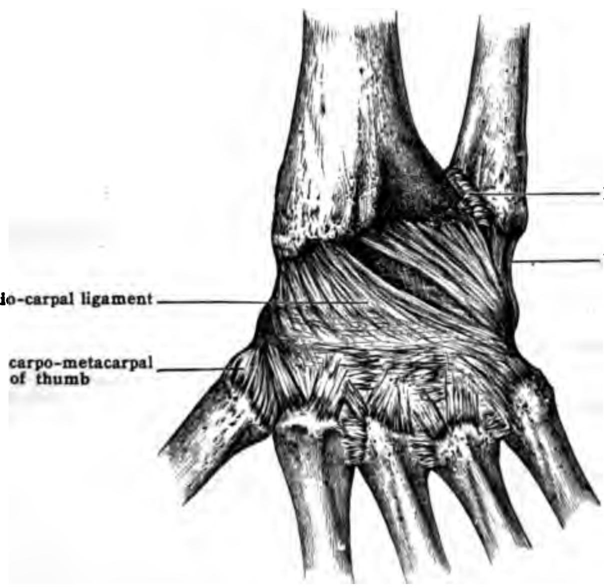
The **ulnar collateral ligament** (fig. 301) is fan-shape
the styloid process of the ulna, to which it is attached c

the apex of the articular disc. Some of the fibres pass forward and laterally to the base of the pisiform bone and to the medial part of the upper border of the transverse carpal ligament, where it is attached to the pisiform bone; they form a thick, rounded fasciculus on the front of the wrist. Other fibres descend vertically to the medial side of the triquetral bone, and others again laterally to the dorsal surface of the triquetral. The tendon of the *extensor carpi ulnaris* is posterior to, and passes over, part of the fibres of the ligament.

The **radial collateral ligament** (fig. 300) consists of fibres which radiate from the fore part and tip of the styloid process of the radius. Some pass downward and medially, in front, to the navicular and adjacent edge of the capitate; some downward, a little forward and medially, to the tubercle of the navicular and ridge of the greater multangular; and others downward and laterally to the rough dorsal surface of the navicular.

The fibres of this ligament are not so long and strong, nor do they radiate so much as those of the ulnar collateral ligament. It is in relation with the *radial artery*, and the *abductor pollicis longus* (*extensor ossis metacarpi pollicis*) and *extensor pollicis brevis*, the artery separating the tendons from the ligament.

FIG. 301.—POSTERIOR VIEW OF WRIST.



The **synovial membrane** is extensive, but does not usually communicate with the synovial membrane of the inferior radio-ulnar joint, being shut out by the articular disc. It is also excluded, in almost every instance, from that of the carpal joints by the interosseous ligaments between the first row of carpal bones. The styloid process of the radius is cartilage-covered medially, and forms part of the articular cavity, while that of the ulna does not.

The **arterial supply** is derived from the anterior and posterior carpal rami, the dorsal division of the volar interosseous, and from twigs direct from the radial and ulnar arteries.

The **nerve-supply** is derived from the ulnar and median in front, and the deep branch of the radial (posterior interosseous) behind.

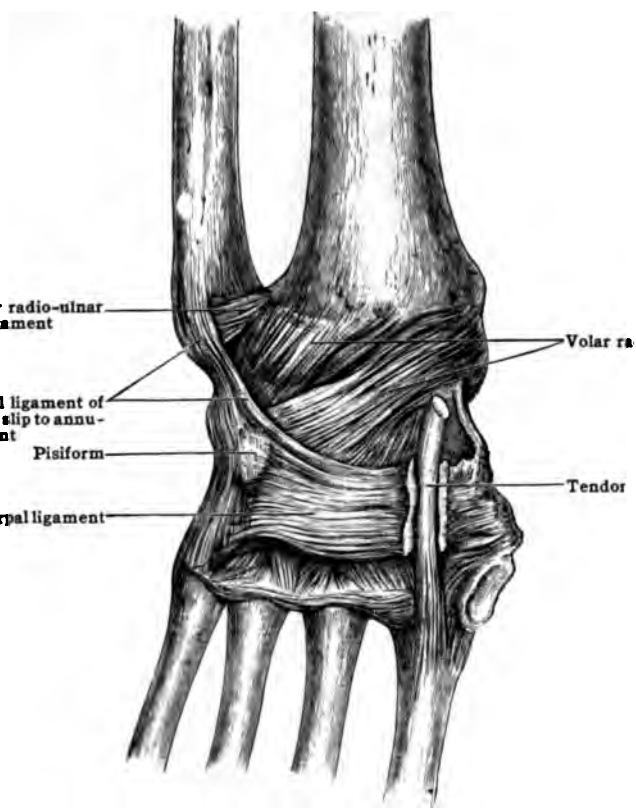
Relations.—In front of the radio-carpal joint are the tendons of the flexor muscles of the wrist and fingers, the synovial sheaths associated with them, the radial and ulnar arteries, and the median and ulnar nerves.

Behind the joint are the majority of the tendons of the extensor muscles of the wrist and fingers, with their synovial sheaths, the terminal part of the anterior and posterior interosseous arteries, and the deep branch of the radial nerve (posterior interosseous). On the radial side lie the tendons of the abductor pollicis longus (*extensor ossis metacarpi pollicis*) and the extensor pollicis brevis. On the ulnar side the joint is subcutaneous and it is crossed by the dorsal cutaneous branch of the ulnar nerve.

Movements.—The wrist is a condyloid joint, the carpus forming the condyle. It allows of movements upon a transverse axis, i. e., flexion and extension; and around an antero-posterior axis, i. e., abduction and adduction; together with a combination of these in quick succes-

cumduction. Lacking only rotation on a vertical axis, it thus posse
nts of a ball-and-socket joint, without the weakness and liability to d
liar to these joints. This deficiency of rotation is compensated for by
adius at the radio-ulnar joints, viz., supination and pronation. Its s
ipon the number of tendons which pass over it, and the close connect
ı the fibrous tissue of their sheaths and the capsule of the wrist; also upo
medio-carpal and carpo-metacarpal joints, which permits shocks and j
tributed between them; another source of strength is the absence of any l
ide of the joint. In flexion and extension the carpus rolls backward and
beneath the arch formed by the radius and articular disc; flexion being
ligament and dorsal portions of the collateral; extension by the volar, an
collateral ligaments. In adduction and abduction the carpal bones glid
radial side and from the radial to the ulnar side, respectively. Abductio
adduction, and is checked by the ulnar collateral ligament and by conta
ss of the radius with the greater multangular; adduction is checked by the
nent alone. One reason for adduction being more free than abduction is th

FIG. 302.—FRONT OF WRIST WITH TRANSVERSE CARPAL LIGAME



iot reach so low down as the radius, and the yielding articular disc allow
ıpward of the ulnar end of the carpus. In circumduction the hand mc
one, the apex of which is at the wrist. These movements are made m
y the slight gliding of the carpal bones upon one another, and the cor
t the medio-carpal joint. The oblique direction of the fibres of the c
ents any rotation at the radio-carpal joint, while it permits considerab
nd adduction.

Muscles which act upon the radio-carpal joint.—*Flexors.*—The fl
he long flexors of the fingers and the thumb, and the palmaris longus.
ors of the carpus and fingers. *Abductors.*—Extensor carpi radialis
icis longus (extensor ossis metacarpi pollicis. *Adductors.*—Flexor ca
ılnaris.

7. THE CARPAL JOINTS

The joints of the carpus may be subdivided into—

(*a*) The **joints of the first row.**
(*b*) The **joints of the second row.**
(*c*) The **medio-carpal,** or junction of the two rows

(a) The Joints of the First Row of Carpal Bones

Class.—*Diarthrosis*. **Subdivision.**—*Arthrodia*.

The bones of the first row, the pisiform excepted, are united by two sets of ligaments and two interosseous fibro-cartilages.

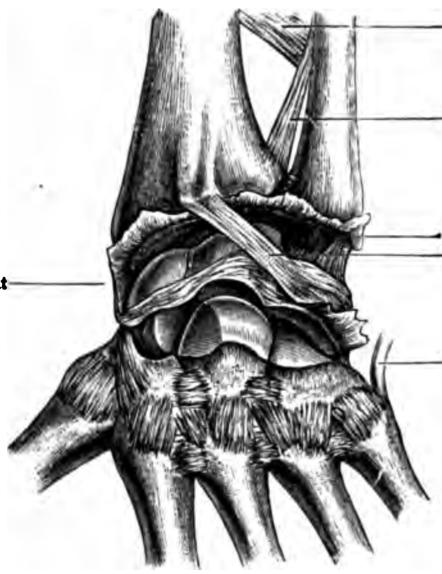
Dorsal. Volar.
Interosseous.

The two dorsal intercarpal ligaments extend transversely between the bones, and connect the navicular with the lunate, and the lunate with the triquetral. Their posterior surfaces are in contact with the posterior ligament of the wrist.

The two volar intercarpal ligaments extend nearly transversely between the bones connecting the navicular with the lunate, and the lunate with the triquetral. They are stronger than the dorsal ligaments, and are placed beneath the anterior ligament of the wrist.

The two interosseous intercarpal ligaments (fig. 304) are interposed between the navicular and lunate, and the lunate and triquetral bones, reaching from the dorsal to the volar surfaces,

Fig. 303.—Posterior View of the Wrist, with Capsule cut to show Articular Surfaces.



and being connected with the dorsal and volar ligaments. They are narrow fibro-cartilages which extend between small portions only of the osseous surfaces. They help to form the convex carpal surface of the radio-carpal joint, and are somewhat wedge-shaped, their bases being toward the wrist, and their thin edges between the adjacent articular surfaces of the bones.

The **synovial membrane** is a prolongation from that of the medio-carpal joint.

The **arterial** and **nerve-supplies** are the same as for the medio-carpal joint.

The Joint of the Pisiform Bone with the Triquetral

This is an arthrodial joint which has a loose fibrous **capsule** attached to both the pisiform and triquetral bones just beyond the margins of their articular surfaces.

It is lined by a separate synovial membrane. Two strong rounded or flattened bands pass downward from the pisiform, one to the process of the hamate [lig. pisohamatum], and the other [lig. pisometacarpeum] to the bases of the third to fifth metacarpals; these are regarded as prolongations of the tendon of the *flexor carpi ulnaris*, and the pisiform bone may be looked upon in the light of a sesamoid bone developed in that tendon.

(b) The Joints of the Second Row of Carpal Bones

Class.—*Diarthrosis*. **Subdivision.**—*Arthrodia*.

The four bones of this row are united by three dorsal, three palmar, and three interosseous ligaments.

The three dorsal ligaments (fig. 303) extend transversely and connect the greater with the r multangular, the lesser multangular with the capitate, and the capitate with the hamate.

The three volar ligaments are stronger than the dorsal, and are deeply placed beneath the is of flexor tendons; they extend transversely between the bones in a similar manner to the sal ligaments.

Three interosseous ligaments connect the bones of the lower row of the carpus together. ro are connected with the capitate, one uniting it with the hamate (fig. 304) and the other iding it to the lesser multangular. The third ligament joins the greater and lesser multangular.

The synovial membrane is a prolongation of that lining the medio-carpal joint.

The arterial and nerve-supplies are the same as for the medio-carpal joint.

c) The Medio-carpal Joint, or the Union of the Two Rows of the Carpus with each other

(I) Class.—*Diarthrosis.* Subdivision.—*Arthrodia.*
(II) Class.—*Diarthrosis.* Subdivision.—*Condylarthrosis.*

The inferior surfaces of the bones of the first row are adapted to the superior articular surfaces of the bones of the second row. The line of this articulation is concavo-convex from side to side, and is sometimes described as having the course of a Roman S placed horizontally, ∽, a resemblance by no means strained. (i) The lateral part of the first row consists of the navicular alone; it is convex, and bears the greater and lesser multangulars. (ii) Then follows a transversely elongated socket formed by the medial part of the navicular, the lunate, and triquetral, into which are received—(*a*) the head of the capitate, which articulates with the navicular and lunate; (*b*) the upper and lateral angle of the hamate, which articulates with the navicular; and (*c*) the upper convex portion of the medial surface of the hamate, which articulates with the lateral and concave portion of the inferior surface of the triquetral. (iii) The medial part of the inferior surface of the triquetral bone is convex, and turned a little backward to fit into the lower portion of the medial surface of the hamate, which is a little concave and turned forward to receive it. The central part, which forms a socket for the capitate and hamate, has somewhat the character of a condyloid joint, the capitate and hamate being the condyle, to fit into the cavity formed by the navicular, lunate, and triquetral; the other portions are typically arthrodial. The ligaments are:—(1) **radiate or anterior medio-carpal**; (2) **posterior medio-carpal**; (3) **transverse dorsal.**

The **radiate,** anterior or volar medio-carpal is a ligament of considerable strength, consisting mostly of fibres which radiate from the capitate to the navicular, lunate, and triquetral; some few fibres connect the greater and lesser multangular with the navicular, and others pass between the hamate and triquetral. It is covered over and thickened by fibrous tissue derived from the sheaths of the flexor tendons and the fibres of origin of the small muscles of the thumb and little finger.

The posterior or **dorsal medio-carpal ligament,** consists of fibres passing obliquely from the bones of the first row to those of the second. It is stronger on the ulnar side than on the radial, but is not so strong as the volar ligament.

The **transverse dorsal ligament** (fig. 303) is an additional band, well marked and often of considerable strength, which passes across the head of the capitate from the navicular to the triquetral bone; besides binding down the head of the capitate, it serves to fix the upper and lateral angle of the hamate in the socket formed by the first row.

The dorsal ligaments, like the volar, are strengthened by a quantity of fibrous tissue belonging to the sheaths of the extensor tendons, and by an extension of some of the fibres of the capsule of the wrist. There are no proper collateral medio-carpal ligaments; they are but prolongations of the collateral ligaments of the wrist.

The **synovial membrane** (fig. 304) of the carpus is common to all the joints of the carpus, and extends to the bases of the four medial metacarpal bones. Thus, besides lining the inter- or medio-carpal joint, it sends two processes upward between the three bones of the first row, and three downward between the contiguous surfaces of the lesser and greater multangular, the lesser multangular and capitate, and capitate and hamate. From these latter, prolongations extend to the four medial carpo-metacarpal joints and the three intermetacarpal joints.

The **arterial supply** is derived from—(*a*) the volar and dorsal carpal rami of the radial and ulnar arteries; (*b*) the carpal branch of the volar interosseous; (*c*) the recurrent branches from the deep palmar arch. The terminal twigs of the volar and dorsal interosseous arteries supply the joint on its dorsal aspect.

The **nerve-supply** comes from the ulnar on the ulnar side, the median on the radial side, and the deep branch of the radial (posterior interosseous) behind.

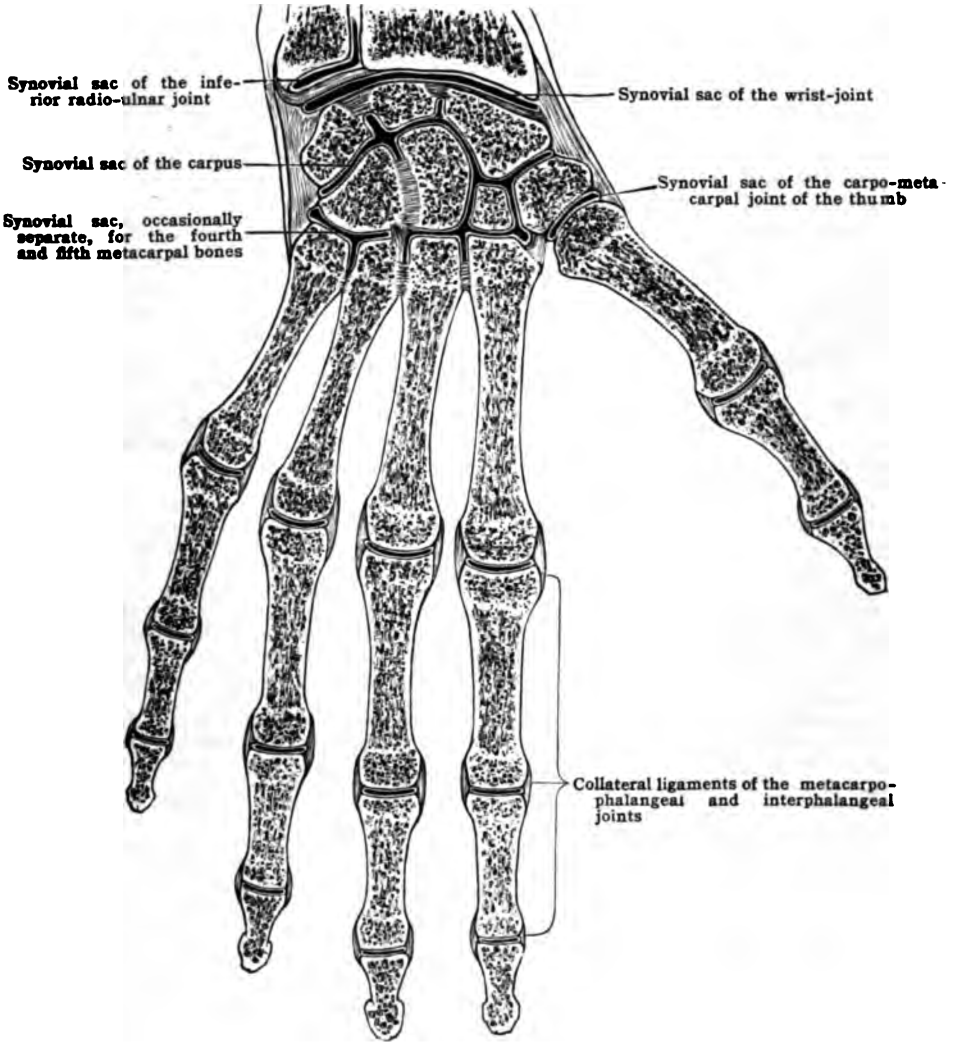
Relations.—The relations of this joint are practically the same as those of the radio-carpal joint, except that the flexor carpi ulnaris does not cross the front, the ulnar artery is separated

from it by the transverse carpal ligament, and the radial artery passes across its lateral border instead of in front.

The movements of the carpal articulations between bones of the same row are very limited and consist only of slight gliding upon one another; but, slight as they are, they give elasticity to the carpus to break the jars and shocks which result from blows or falls upon the hand.

The movements of one row of bones upon the other at the medio-carpal joint are more extensive, especially in the direction of flexion and extension, so that the hand enjoys a greater range of these movements than is permitted at the wrist-joint alone. At the wrist, extension is more free than flexion; but this is balanced by the greater freedom of flexion than of extension at the medio-carpal joint, and by flexion at the carpo-metacarpal joint, so that on the whole the range of flexion of the hand is greater than that of extension.

FIG. 304.—SYNOVIAL MEMBRANES OF WRIST, HAND, AND FINGERS.



A slight amount of side to side motion accompanied by a limited degree of rotation also takes place; this rotation consists in the head of the capitate and the superior and lateral angle of the hamate bone rotating in the socket formed by the three bones of the upper row, and in a gliding forward and backward of the greater and lesser multangular upon the navicular.

In addition to the ligaments, the undulating outline and the variety of shapes of the apposed facets render this joint very secure.

Bearing in mind the mobility of this medio-carpal joint and of the carpo-metacarpal, we see at once the reason for the radial and ulnar flexors and extensors of the carpus being prolonged down to their insertion into the base of the metacarpus, for they produce the combined effect of motion at each of the three transverse articulations:—(1) at the wrist; (2) at the medio-carpal; (3) at the carpo-metacarpal joints.

Muscles which act upon the mid-carpal joint.—The muscles which act upon this joint are the same as those which act upon the radio-carpal joint, except the flexor carpi ulnaris, which is inserted into the pisiform bone.

8. THE CARPO-METACARPAL JOINTS

These may be divided into two sets, namely:—

(*a*) The **carpo-metacarpal joints of the four medial fingers.**
(*b*) The **carpo-metacarpal joints of the thumb.**

The inferior surfaces of the bones of the second row of the carpus present a composite surface for the four medial metacarpal bones; the greater multangular presents in addition a distinct and separate saddle-shaped surface for the base of the metacarpal bone of the thumb.

(*a*) The Four Medial Carpo-metacarpal Joints

Class.—*Diarthrosis*. **Subdivision.**—*Arthrodia.*

These joints exist between the greater and lesser multangular, capitate, and hamate bones above, and the four medial metacarpal bones below. The ligaments which unite them are, dorsal, volar, and interosseous.

The dorsal ligaments (fig. 303).—Three dorsal ligaments pass to the second metacarpal bone: one from each of the carpal bones with which it articulates, viz., the greater and lesser multangular, and capitate. Two dorsal bands pass from the capitate to the third metacarpal bone. Two dorsal bands pass to the fourth bone: viz., one from the hamate, and another from the capitate; the latter is sometimes wanting. The fifth bone has only one band passing to it from the hamate.

The volar ligaments (fig. 300).—One strong band passes from the second metacarpal bone to the greater multangular medial to the ridge for the transverse carpal ligament; it is covered by the sheath of the *flexor carpi radialis.*

Three bands pass from the third metacarpal: one laterally to the greater multangular, a middle one upward to the capitate, and a third medially over the fourth to reach the fifth metacarpal and the hamate bones.

One ligament connects the fourth bone to the hamate.

One ligament connects the fifth bone to the hamate, the fibres extending medially, and connecting the dorsal and volar ligaments. The ligament to the fifth bone is strengthened in front by the prolonged fibres of the *flexor carpi ulnaris* and the strong medial slip of the ligament of the third metacarpal bone; and posteriorly, by the tendon of the *extensor carpi ulnaris.*

The **interosseous ligament** (fig. 304) is limited to one part of the articulation, and consists of short fibres connecting the contiguous angles of the hamate and capitate with the third and fourth metacarpal bones toward their volar aspect. There is, however, a thick strong ligament connecting the edge of the greater multangular with the lateral border of the base of the second metacarpal bone; it helps to separate the carpo-metacarpal joint of the thumb from the common carpo-metacarpal joint, and to close in the radial side of the latter joint.

The **synovial membrane** is a continuation of the medio-carpal joint; occasionally there is a separate membrane between the hamate and fourth and fifth metacarpal bones (fig. 304); while that between the fourth and capitate is lined by the synovial sac of the common joint.

The **arteries** to the four medial carpo-metacarpal joints are as follows:—

(1) For the index finger: twigs are supplied by the trunk of the radial on the dorsal and volar aspects, and by the dorsal and volar metacarpal branches.

(2) For the middle finger: the first dorsal metacarpal by the branch which passes upward to join the dorsal carpal arch, and a branch from the deep volar arch which joins the volar carpal arch.

(3) For the ring finger: the deep volar arch and recurrent twigs from the second dorsal metacarpal in the same manner as for the middle finger.

(4) For the little finger: the ulnar and its deep branch; also twigs from the second dorsal metacarpal.

The **nerves** are supplied to these joints by the deep volar branch of the ulnar, the deep branch of the radial (posterior interosseous), and the median.

Relations.—In front of the four medial carpo-metacarpal joints are the flexors of the fingers with their synovial sheath. The flexor carpi radialis crossing in front of the lateral part of the joint and the fibres of the oblique adductor pollicis which spring from the capitate and lesser multangular are also anterior relations. Behind the joints are the extensors of the wrist and fingers with their synovial sheaths and the dorsal metacarpal arteries. At the lateral border of the joints between the index and lesser multangular lies the radial artery.

The **movements** permitted at these joints, though slight, serve to increase those of the medio-carpal and wrist-joints. The joint between the fifth metacarpal and the hamate bones approaches somewhat in shape and mobility the first carpo-metacarpal joint; it has a greater range of flexion and extension, but its side to side movement is nearly as limited as that of the three other metacarpal bones; the process of the hamate bone limits its flexion. Motion toward the ulnar side is checked by the strong palmar band which unites the base of the fifth metacarpal to the base of the third, and the strong transverse ligament at the head of the bones. The mobility of the second, third, and fourth metacarpal bones is very limited, and consists almost entirely of a slight gliding upon the carpal bones, i. e., flexion and extension; that of the *third* and fourth bones is extremely slight, as there is no long flexor attached to either; but,

owing to the close connection of the bases of the metacarpal bones, the radial and ulnar flexors and extensors of the carpus act on all by their pull on the particular bone into which they are inserted.

Abduction, or movement toward the radial side, is prevented by the impaction of the second bone against the greater multangular; a little adduction is permitted, and is favoured by the slope given to the hamate and fifth metacarpal bones.

There is also a slight gliding between the fourth and fifth bones, when the concavity they present toward the palm is deepened to form the 'cup of Diogenes.'

Muscles which act upon the four medial carpo-metacarpal joints are the flexors and extensors of the wrist and fingers, except the flexor carpi ulnaris.

(b) The Carpo-metacarpal Joint of the Thumb

Class.—*Diarthrosis.* **Subdivision.**—*Saddle-shaped Arthrodia.*

The bones entering into this joint are the base of the first metacarpal and the greater multangular. The first metacarpal bone diverges from the other four, contrasting very strongly with the position of the great toe. It is due to this divergence that the thumb is able to be opposed to each and all the fingers. The ligament which unites the bones is the

Articular capsule.

The **articular capsule** (figs. 300 and 301) consists of fibres which pass from the margin of the articular facet on the greater multangular, to the margin of the articular facet at the base of the first metacarpal bone.

The fibres are stronger on the dorsal than on the palmar aspect. They are not tense enough to hold the bones in close contact, so that while they restrict they do not prevent motion in any direction. The medial fibres are stronger than the lateral.

The **synovial membrane** is lax, and distinct from the other synovial membranes of the carpus.

The **arteries** of the carpo-metacarpal joint of the thumb are derived from the trunk of the radial, the first volar metacarpal, and the dorsalis pollicis.

The **nerves** are supplied by the branches of the median to the thumb.

Relations.—Behind are the long and short extensor tendons of the thumb, and behind and laterally the tendon of the abductor pollicis longus (extensor ossis metacarpi pollicis). The tendon of the flexor pollicis longus is in front and fibres of the flexor pollicis brevis and opponens pollicis muscles are also anterior relations. To the medial side is the radial artery as it passes forward into the palm of the hand.

The **movements** of this joint are regulated by the shape of the articular surfaces, rather than by the ligaments, and consist of flexion, extension, abduction, adduction, and circumduction, but not rotation. In flexion and extension the metacarpal bone slides to and fro upon the multangular; in abduction and adduction it slides from side to side or, more correctly, revolves upon the antero-posterior axis of the joint. The power of opposing the thumb to any of the fingers is due to the forward and medial obliquity of its flexion movement, which is by far its most extensive motion. Abduction is very free, while adduction is limited on account of the proximity of the second metacarpal bone. The movement of the greater multangular upon the rest of the carpus somewhat increases the range of all the movements of the thumb.

Muscles which act upon the carpo-metacarpal joint of the thumb.—*Flexors.*—Flexor pollicis brevis, flexor pollicis longus, opponens pollicis. *Extensors.*—Extensores pollicis brevis and longus and abductor pollicis longus. *Abductors.*—Abductores pollicis longus and brevis. *Adductors.*—The transverse and oblique adductor pollicis, opponens, first dorsal interosseous. *Muscles producing opposition.*—Opponens, flexor brevis, oblique adductor.

9. THE INTERMETACARPAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The metacarpal of the thumb is not connected with any other metacarpal bone. The second, third, fourth, and fifth metacarpal bones are in actual contact at their bases, and are held firmly together by the following ligaments (in addition to the articular capsule):—

Dorsal. Volar.
Interosseous ligaments.

The **dorsal ligaments** (fig. 302) are layers of variable thickness of strong, short fibres, which pass transversely from bone to bone, filling up the irregularities on the dorsal surfaces.

The **volar ligaments** are transverse layers of ligamentous tissue passing from bone to bone; they cannot be well differentiated from the other ligaments and fibrous tissue covering the bones.

The **interosseous ligaments** (fig. 304) pass between the apposed surfaces of the bones, and are attached to the distal sides of the articular facets, so as to close in the synovial cavities on

this aspect; where there are two articular facets, the fibres extend upward between them nearly as far as their carpal facets. That between the fourth and fifth is the weakest.

The **synovial membrane** is prolonged downward from the common carpal sac.

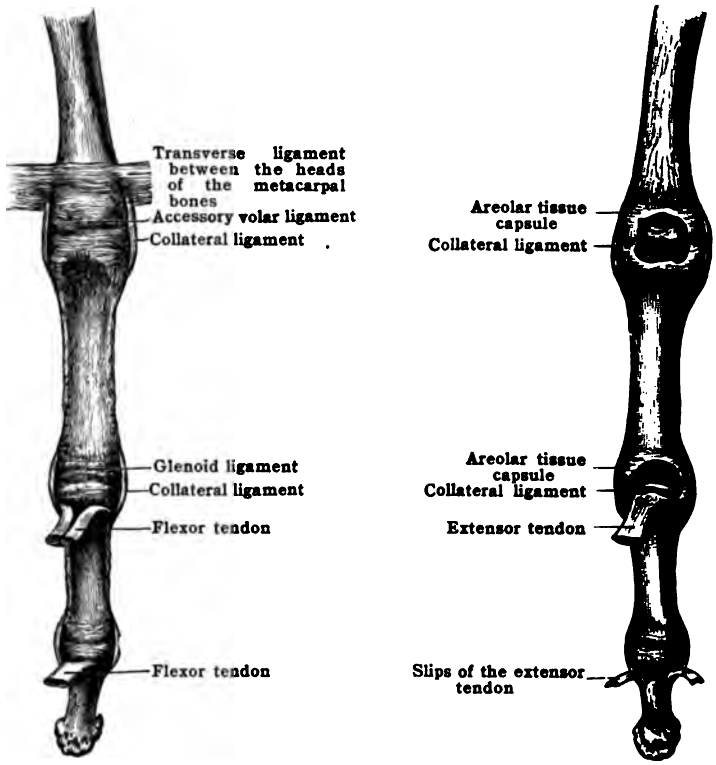
The **arteries** to the intermetacarpal joints are twigs from the volar and dorsal metacarpal arteries; the twigs pass upward between the interosseous muscles.

The **nerves** are derived from the ulnar and the deep branch of radial (posterior interosseous).

The Union of the Heads of the Metacarpal Bones

The distal extremities of these bones are connected together on their palmar aspects by what is called the **transverse ligament** [lig. capitulorum]. This consists of three short bands of fibrous tissue, which unite the second and third, third and fourth, and the fourth and fifth bones. They are rather more than 6 mm. (¼ in.) deep, and rather less in width, and limit the distance to which the metacarpal bones can be separated. They are continuous above with the fascia covering the interosseous muscles; below, they are connected with the subcutaneous tissue of the web of the hand. They are on a level with the front surface of the bones, and are blended on either side with the edges of the glenoid ligament in front, with the lateral ligaments

Fig. 305.—Anterior and Posterior Views of Ligaments of the Fingers.



of the metacarpo-phalangeal joint, and also with the sheaths of the tendons. In front, a *lumbrical* muscle passes with the digital arteries and nerves; while behind, the *interossei* muscles pass to their insertions.

10. THE METACARPO-PHALANGEAL JOINTS

(a) The Metacarpo-phalangeal Joints of the Four Medial Fingers

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

In these joints the cup-shaped extremity of the base of the first phalanx fits on to the rounded head of the metacarpal bone, and is united by the following ligaments (in addition to the articular capsule):—

Collateral. Volar accessory.

The **volar accessory** (or glenoid) **ligament** (fig. 305) is a fibro-cartilaginous plate which seems more intended to increase the depth of the phalangeal articular facet in front, than to unite the two bones. It is much more firmly attached to the margin of the phalanx than to the metacarpal bone, being only loosely connected with the palmar surface of the latter by some loose areolar tissue which covers in the synovial membrane, here prolonged some little distance *upon the surface* of the bone. At the sides, it is connected with the collateral ligaments and the

transverse metacarpal ligament. It corresponds to the sesamoid bones of the thumb; a sesamoid bone sometimes exists at the medial border of the joint of the little finger.

The **collateral ligaments** (304 and 305) are strong and firmly connect the bones with one another; each is attached above to the corresponding tubercle, and to a depression in front of the tubercle, of the metacarpal bone. From this point the fibres spread widely as they descend on either side of the base of the phalanx; the anterior fibres are connected with the glenoid ligament; the posterior blend with the tendinous expansion at the back of the joint.

The joint is covered in posteriorly by the expansion of the extensor tendon, and some loose areolar tissue passing from its under surface to the bones (fig. 305).

The **synovial membrane** is loose and capacious, and invests the inner surface of the ligaments which connect the bones.

The **arteries** come from the digital or volar metacarpal vessels of the deep arch.

The **nerves** are derived from the digital branches, or from twigs of the branches of the ulnar to the interosseous muscles.

Relations.—I. The metacarpo-phalangeal joints of the middle three digits. In front, the tendons of the flexor profundus and flexor sublimis digitorum. On the radial side, a lumbrical, an interosseous muscle, and digital nerves and vessels; on the ulnar side, an interosseous muscle and digital vessels and nerves. Behind, the common extensor tendon and in the case of the index digit the tendon of the extensor indicis.

II. The metacarpo-phalangeal joint of the little finger. In front, the flexor quinti digiti brevis and the tendons of the flexor profundus and sublimis digitorum muscle which go to this digit. Behind, the extensor digiti quinti to a slip of the extensor digitorum communis sometimes. On the radial side, a lumbrical, the third palmar interosseous muscle, digital vessels and nerves. On the ulnar side, digital vessels and nerves.

The **movements** permitted at these joints are flexion, extension, abduction, adduction, and circumduction. Flexion is the most free of all and may be continued until the phalanx is at a right angle with the metacarpal bone. It is on this account that the articular surface of the head of the bone is prolonged so much further on the palmar aspect, and that the synovial membrane is here so loose and ample. Extension is the most limited of the movements, and can only be carried to a little beyond the straight line. Abduction and adduction are fairly free, but not so free as flexion. Flexion is associated with adduction, and extension with abduction. This may be proved by opening the hand, when the fingers involuntarily separate as they extend, while in closing the fist they come together again. The free abduction, adduction, and circumduction which are permitted at these joints are due to the fact that the long axes of the articular facets are at right angles to one another.

Muscles acting on the middle three digits.—*Flexors.*—Flexor digitorum profundus, flexor digitorum sublimis. *Extensors.*—Extensor digitorum communis and on the index digit the extensor indicis. *Abductors.*—Dorsal interossei. *Adductors.*—Volar interossei.

Muscles acting on the metacarpo-phalangeal joint of the little finger.—*Flexors.*—Flexor quinti digiti brevis, flexor digitorum sublimis, flexor digitorum profundus. *Extensors.*—Extensor digitorum communis, extensor quinti digiti. *Abductor.*—Abductor quinti digiti. *Adductor.*—Third volar interosseous.

(b) The Metacarpo-phalangeal Joint of the Thumb

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

The head of the metacarpal bone of the thumb differs considerably from the corresponding ends of the metacarpal bones of the fingers. It is less convex, wider from side to side, the palmar edge of the articular surface is raised and irregular, and here on either side of the median line are the two facets for the sesamoid bones. The base of the first phalanx of the thumb, too, is more like the base of the second phalanx of one of the other fingers. The ligaments are:—

Collateral. Dorsal.
Articular capsule.

The **collateral ligaments** are short, strong bands of fibres, which radiate from depressions on either side of the head of the metacarpal bone to the base of the first phalanx and sesamoid bones. As they descend they pass a little forward, so that the greater number are inserted in front of the centre of motion.

The **dorsal ligament** consists of scattered fibres which pass across the joint from one collateral ligament to the other, completing the **articular capsule** and protecting the synovial sac.

The **sesamoid bones** are two in number, situated on either side of the middle line, and connected together by strong transverse fibres which form the floor of the groove for the *long flexor tendon;* they are connected with the base of the phalanx and head of the metacarpal bone by strong fibres. Anteriorly they give attachment to the short muscles of the thumb, and posteriorly are smooth for the purpose of gliding over the facets. The collateral ligaments are partly inserted into their sides.

The **arteries** and **nerves** come from the digital branches of the thumb.

Relations.—Of the metacarpo-phalangeal joint of the thumb: In front and externally abductor pollicis brevis and superficial head of flexor pollicis brevis. In front and medially oblique and transverse adductors and deep head of flexor pollicis brevis. Directly in front flexor pollicis longus and terminal branches of first volar metacarpal artery. Behind, extensor pollicis brevis and longus tendons. On either side, the dorsal digital vessels and the digital nerves.

The **movements** are chiefly flexion and extension, very little side to side movement being permitted, and that only when the joint is slightly bent. Thus this joint more nearly approaches the simple hinge character than the corresponding articulations of the fingers. The thumb gets its freedom of motion at the carpo-metacarpal joint; the fingers get theirs at the metacarpo-phalangeal, but they are not endowed with so much freedom as the thumb enjoys.

Muscles which act upon the metacarpo-phalangeal joint of the thumb.—*Flexors.*—Flexor pollicis brevis, flexor pollicis longus. *Extensors.*—Extensor pollicis brevis, extensor pollicis longus.

11. THE INTERPHALANGEAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The ligaments which unite the phalanges of the thumb and of the fingers are (in addition to the articular capsule):—

Accessory volar. Collateral.

The **accessory volar** (or glenoid) **ligament** (fig. 305), sometimes called the sesamoid body, is very firmly connected with the base of the distal bone, and loosely, by means of fibro-areolar tissue, with the head of the proximal one. It blends with the collateral ligaments at the sides, and over it pass the flexor tendons. Occasionally a sesamoid bone is developed in the cartilage of the interphalangeal joint of the thumb.

The **collateral ligaments** (figs. 304 and 305) are strong bands which are attached to the rough depressions on the sides of the upper phalanx, and to the projecting margins of the lower phalanx of each joint. They are tense in every position, and entirely prevent any side to side motion; they are connected posteriorly with the expansion of the extensor tendon.

Dorsally (fig. 305) the joint is covered in by the deep surface of the extensor tendon, and a little fibro-areolar tissue extends from the tendon, and thickens the posterior portion of the synovial sac, completing the **articular capsule.**

The **synovial membrane** is loose and ample, and extends upward a little way along the shaft of the proximal bone.

The **arteries** and **nerves** come from their respective digital branches.

The **relations** of the interphalangeal joints are the flexor and extensor tendons and the digital vessels and nerves.

The **movements** are limited to flexion and extension. Flexion is more free, and can be continued till one bone is at a right angle to the other, and is most free at the junction of the first and second bones; the second phalanx can be flexed on the first through 110° to 115° when the latter is not flexed. The greater freedom of flexion is due to the greater extent of the articular surface in front of the heads of the proximal bones, and to the direction of the fibres of the collateral ligaments, which pass a little forward to their insertion into the distal bone.

The **muscles** which act upon the interphalangeal joints are the extensors and flexors of the digits.

THE ARTICULATIONS OF THE LOWER LIMB

The articulations of the lower limb are the following:—

1. The **hip-joint.**
2. The **knee-joint.**
3. The **tibio-fibular union.**
4. The **ankle-joint.**
5. The **tarsal joints.**
6. The **tarso-metatarsal joints.**
7. The **intermetatarsal joints.**
8. The **metatarso-phalangeal joints.**
9. The **interphalangeal joints.**

1. THE HIP-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Enarthrodia.*

The hip is the most typical example of a ball-and-socket joint in the body, the round head of the femur being received into the cup-shaped cavity of the acetabulum. Both articular surfaces are coated with cartilage, that covering the head of the femur being thicker above where it has to bear the weight of the body, and thinning out to a mere edge below; the pit for the ligamentum teres is the only part uncoated, but the cartilage is somewhat heaped up around its margin. Covering the acetabulum, the cartilage is horseshoe-shaped, and thicker above than below, being deficient over the depression at the bottom of the acetabulum,

where a mass of fatty tissue—the so-called synovial or Haversian gland—is lodged.

The ligaments of the joint are:—

Articular capsule.	Ligamentum teres.
Transverse.	Glenoid lip.

The **articular capsule** is one of the strongest ligaments in the body. It is large and somewhat loose, so that in every position of the body some portion of it is relaxed. At the **pelvis** it is attached, superiorly, to the base of the anterior inferior iliac spine; curving backward, it becomes blended with the deep surface of the reflected tendon of the *rectus femoris;* posteriorly, it is attached a few millimetres from the acetabular rim; and below, to the upper edge of the groove between the acetabulum and tuberosity of the ischium. Thus it reaches the

FIG. 306.—ANTERIOR VIEW OF THE ARTICULAR CAPSULE OF THE HIP-JOINT.

transverse ligament, being firmly blended with its outer surface, and frequently sends fibres beyond the notch to blend with the obturator membrane. Anteriorly it is attached to the pubis near the obturator notch, to the ilio-pectineal eminence and thence backward to the base of the inferior iliac spine.

A thin strong stratum is given off from its superficial aspect behind; this extends beneath the gluteus minimus and small rotators, to be attached above to the dorsum of the ilium higher than the reflected tendon of the rectus, and posteriorly to the ilium and ischium nearly as far as the sciatic notch. As this expansion passes over the long tendon of the *rectus*, the tendon may be described as being in part contained within the substance of the capsule.

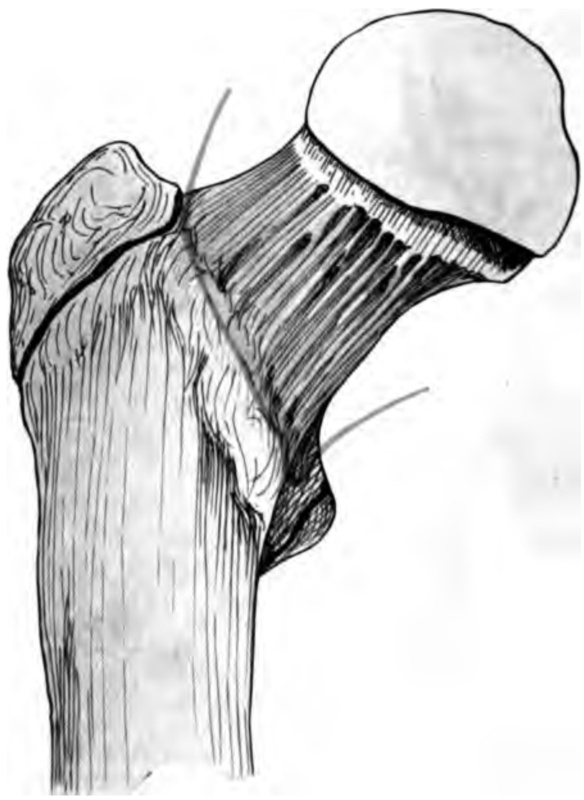
At the **femur,** the capsule is fixed to the anterior portion of the upper border of the great trochanter and to the cervical tubercle. Thence it runs down, the intertrochanteric line as far as the medial border of the femur, where it is on a level with the lower part of the lesser trochanter. It then runs upward and backward along an oblique line about 1.6 cm. ($\frac{2}{3}$ in.) in front of the lesser trochanter, and continues its ascent along the back of the neck nearly parallel to the intertrochanteric crest, and from 12 to 16 mm. ($\frac{1}{2}$ to $\frac{2}{3}$ in.) above it; finally, it passes along the medial side of the trochanteric fossa to reach the anterior superior angle of the great trochanter.

On laying open the capsule, some of the deeper fibres are seen reflected upward along th— neck of the femur, to be attached much nearer the head: these are the **retinacula.** One corre— sponds to the upper, and another to the lower, part of the intertrochanteric line; a third is see— at the upper and back part of the neck. They form flat bands,which lie on the femoral neck—

Superadded to the capsule, and considerably strengthening it, are three auxil— iary bands, whose fibres are intimately blended with, and in fact form part of — the capsule, viz., the ilio-femoral, ischio-capsular, and pubo-capsular ligaments—

The **ilio-femoral ligament** (fig. 306) is the longest, widest, and strongest of the bands— It is of triangular shape, with the apex attached above to a curved line on the ilium immediately— below and behind the anterior inferior spine, and its base below to the anterior edge of the— greater trochanter and to the spiral line as far as the medial border of the shaft. The highest or— most lateral fibres are coarse, almost straight, and shorter than the rest; the most medial fibres are also thick and strong, but oblique. This varying obliquity of the fibres, and their accumula— tion at the borders, explain why this band has been described as the Y-shaped ligament; but it

FIG. 307.—UPPER EXTREMITY OF THE FEMUR (ANTERIOR VIEW), TO SNOW THE RELATION OF THE ARTICULAR CAPSULE OF THE HIP-JOINT (IN RED) TO THE EPIPHYSIAL LINES.



should be noted that the Y is inverted. About the centre of its base, near the femoral attachment, is an aperture transmitting an articular twig from the ascending branch of the external circumflex artery.

The **ischio-capsular ligament** (fig. 308) is formed of very strong fibres attached all along the upper border of the groove for the external obturator, and to the ischial margin of the acetabulum above the groove. The highest of these incline a little upward as they pass laterally to be fixed to the greater trochanter in front of the insertion of the piriformis tendon, while the other fibres curve more and more upward as they pass laterally to their insertion at the inner side of the trochanteric fossa, blending with the insertion of the external rotator tendons. When the joint is in flexion, these fibres pass in nearly straight lines to their femoral attachment, and spread out uniformly over the head of the femur; but in extension they wind over the back of the femur in a zonular manner [zona orbicularis], embracing the posterior aspect of the neck of the femur.

The **pubo-capsular (pectineo-femoral) band** (fig. 306) is a distinct but narrow set of fibres which are individually less marked than the fibres of the other two bands; they are fixed above to the obturator crest and to the anterior border of the ilio-pectineal eminence, reaching as far down as the pubic end of the acetabular notch. Below, they reach the neck of the femur, and *are fixed* above and behind the lowermost fibres of the ilio-femoral band, with which they blend.

In thickness and strength the capsule varies greatly; thus, if two lines be drawn, one from the anterior inferior spine to the medial border of the femur near the lesser trochanter, and the other from the anterior part of the groove for the

FIG. 308.—POSTERIOR VIEW OF THE ARTICULAR CAPSULE OF THE HIP-JOINT.

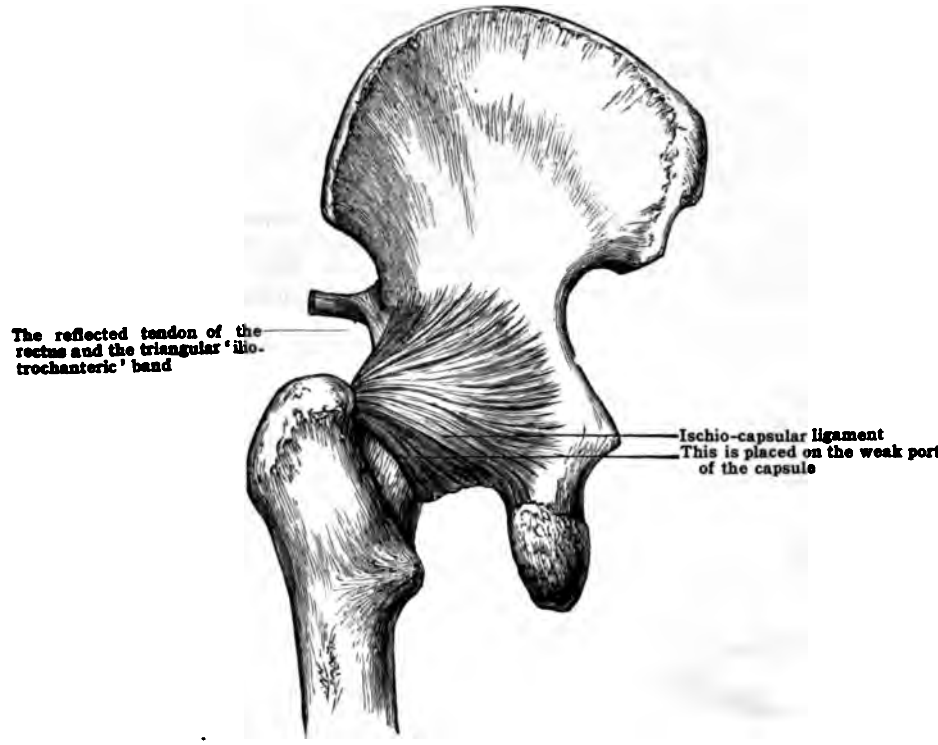
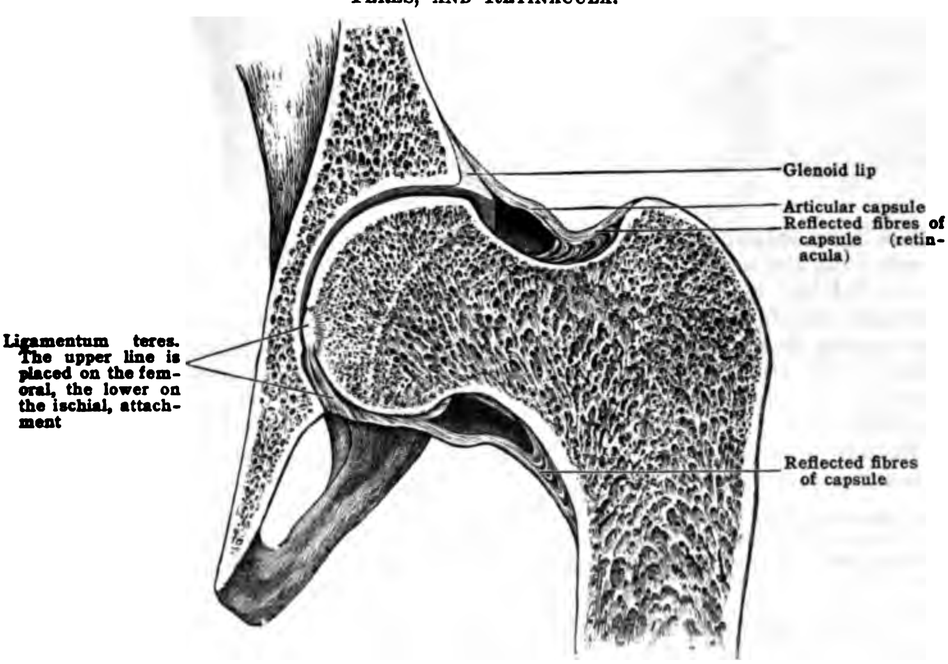


FIG. 309.—SECTION THROUGH THE HIP-JOINT, SHOWING THE GLENOID LIP, LIGAMENTUM TERES, AND RETINACULA.



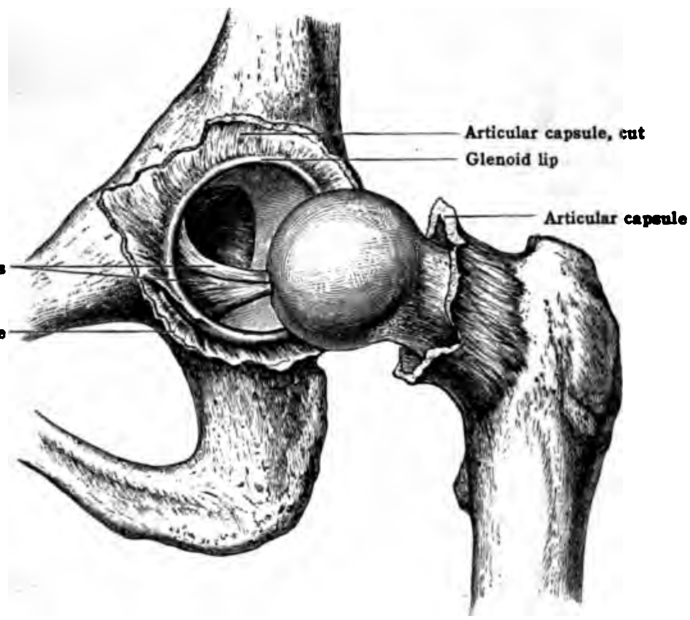
external obturator to the trochanteric fossa, all the ligament between these lines on the lateral and upper aspects of the joint is very thick and strong, while that below and to the medial side, except at the narrow pubo-capsular ligament, is

thin and weak, so that the head of the bone can be seen through it. The capsule is thickest in the course of the ilio-femoral ligament, toward the lateral part of which it measures over 6 mm. (¼ in.). Between the ilio-femoral and ischio-capsular ligaments the capsule is very strong, and with it here, near the acetabulum, is incorporated the reflected tendon of the rectus, and here also a triangular band of fibres runs downward and forward to be attached by a narrow insertion to the ridge on the front border of the greater trochanter near the gluteus minimus (the **ilio-trochanteric band**) (fig. 308).

The capsule is strengthened also at this point by a strong band from the under surface of the gluteus minimus, and by the **tendino-trochanteric band** which passes down from the reflected tendon of the rectus to the vastus lateralis (externus) (fig. 306). This is closely blended with the capsule near the lateral edge of the ilio-femoral ligament.

The thinnest part of the capsule is between the pubo-capsular and ilio-femoral ligaments; this is sometimes perforated, allowing the bursa under the psoas to communicate with the joint. The capsule is also very thin at its attachment to the back of the femoral neck, and again opposite the acetabular notch.

Fig. 310.—Hip-joint after Dividing the Articular Capsule and Disarticulating the Femur.



The **ligamentum teres** (figs. 309 and 310) is an interarticular flat band which extends from the acetabular fossa to the head of the femur, and is usually about 3.7 cm. (1½ in.) long. It has two bony attachments, one on either side of the acetabular notch immediately below the articular cartilage, while intermediate fibres spring from the lower surface of the transverse ligament. The ischial portion is the stronger, and has several of its fibres arising outside the cavity, below and in connection with the origin of the transverse ligament, where it is also continuous with the capsule and periosteum of the ischium. At the femur it is fixed to the front part of the depression on the head, and to the cartilage round the margin of the depression.

It is covered by a prolongation of synovial membrane, which also covers the cushion of fat in the recess of the acetabulum; the portion of the membrane reflected over the fatty tissue does not cling closely to the round ligament, but forms a triangular fold, the apex of which is at the femur.

The **transverse ligament** (fig. 311) passes across the acetabular notch and converts it into a foramen; it supports part of the glenoid fibro-cartilage, and is connected with the ligamentum teres and the capsule. It is composed of decussating fibres, which arise from the margin of the acetabulum on either side of the notch, those coming from the pubis being more superficial, and passing to form

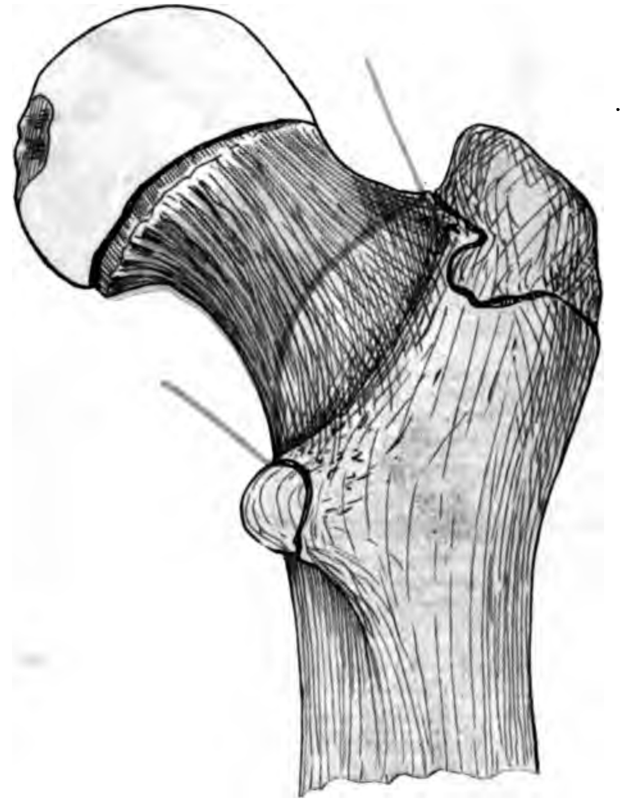
the deep part of the ligament at the ischium, while those superficial at the ischium are deep at the pubis. It thus completes the rim of the acetabulum.

The **glenoid lip** (cotyloid fibro-cartilage) (figs. 309 and 310) is a yellowish-white structure, which deepens the acetabulum by surmounting its margin. It

FIG. 311.—PORTIONS OF ISCHIUM AND PUBIS, SHOWING THE ACETABULAR NOTCH AND THE LIGAMENTUM TERES ATTACHED OUTSIDE THE ACETABULUM.

varies in strength and thickness, but is stronger at its iliac and ischial portions than elsewhere. Its base is broad and fixed to the bony rim as well as to the articular cartilage of the acetabulum on the inner, and the periosteum on the outer, side of it, and blends inseparably with the transverse ligament which supports it over the acetabular notch.

FIG. 312.—THE UPPER EXTREMITY OF THE FEMUR (POSTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE HIP-JOINT (IN RED) TO THE EPIPHYSIAL LINES.



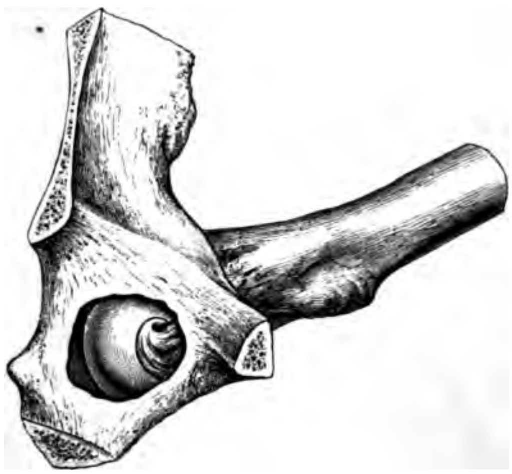
Its free margin is thin; on section it is somewhat lunated, having its outer surface convex and its articular face concave and very smooth in adaptation to the head of the bone, which it tightly embraces a little beyond its greatest circumference. It somewhat contracts the aperture of the acetabulum, and retains the head of the femur within its grasp after division of the muscles and capsular ligament. It is covered on both aspects by synovial membrane.

The **synovial membrane** lines the capsule and both surfaces of the glenoid lip, and passes over the border of the acetabulum to reach and cover the fatty cushion it contains. The part covering the fatty cushion is unusually thick, and is attached round the edges of the rough bony surface on which the cushion rests. The membrane is loosely reflected off this on to the ligamentum teres, along which it is prolonged to the head of the femur; thus the fibres of the round ligament are shut out from the joint cavity. From the capsule the synovial membrane is also reflected below on to the neck of the femur, whence it passes over the retinacula to the margin of the articular cartilage. A fold of synovial membrane on the under aspect of the neck often conveys to the head of the femur a branch of an artery—generally a branch of the medial circumflex.

The **arterial supply** comes from—(*a*) the transverse branches of the medial and lateral circumflex arteries; (*b*) the lateral branch of the obturator sends a branch through the acetabular notch beneath the transverse ligament, which ramifies in the fat at the bottom of the acetabulum, and travels down the round ligament to the head of the femur; (*c*) the inferior branch of the deep division of the superior gluteal; and (*d*) the inferior gluteal (sciatic) arteries. The branch from the obturator to the ligamentum teres is sometimes very large when the branch from the medial circumflex does not also supply the ligament.

The superior and inferior gluteal send several branches through the innominate attachment

FIG. 313.—LIGAMENTUM TERES, LAX IN FLEXION.



of the articular capsule: these anastomose freely beneath the capsule around the outer aspect of the acetabulum, and supply some branches to enter the bone, and others which enter the substance of the glenoid lip. There is quite an arterial crescent upon the posterior and postero-superior portions of the acetabulum; but no vessels are to be seen on the inner aspect of the glenoid lip.

The **nerve-supply** comes from—(*a*) femoral (anterior crural), (*b*) anterior division of the obturator, (*c*) the accessory obturator, and (*d*) the sacral plexus, by a twig from the nerve to the quadratus femoris, or from the upper part of the great sciatic, or from the lower part of the sacral plexus.

Relations.—In *front* and in contact with the capsule are the psoas bursa, the tendinous part of the psoas magnus, and the iliacus. Still more anteriorly and not in contact are the femoral artery, the femoral (anterior crural) nerve, the rectus femoris, the sartorius, and the tensor fasciæ latæ.

Above and in close relation with the capsule are the piriformis, the obturator internus and the gemelli, and the reflected head of the rectus femoris, whilst more superficially lie the gluteus minimus and medius.

Behind and in close relation with the capsule are the obturator externus, the gemelli and obturator internus, and the piriformis. More superficially lie the quadratus femoris, the sciatic nerves, and the gluteus maximus.

Below the obturator externus, the pectineus, and the medial circumflex artery are in close relation with the capsule.

The movements.—The hip-joint, like the shoulder, is a ball-and-socket joint, but with a much more complete socket and a corresponding limitation of movement. Each variety of movement is permitted, viz., flexion, extension, abduction, adduction, circumduction, and rotation; and any two or more of these movements not being antagonistic can be combined, i. e., flexion or extension associated with abduction or adduction can be combined with rotation in or out.

It results from the obliquity of the neck of the femur that the movements of the head in the acetabulum are always more or less of a rotatory character. This is more especially the case during flexion and extension, and two results follow from it. First, the bearing surfaces of the femur and acetabulum preserve their apposition to each other, so that the amount of articular surface of the head in the acetabulum does not sensibly diminish *pari passu* with the transit of the joint from the extended to the flexed position, as would necessarily be the case if the movement of the femoral head, like that of the thigh itself, was simply angular, instead of rotatory and angular. Secondly, as rotation of the head can continue until the ligaments are tight without being checked by contact of the neck of the thigh bone with the rim of the acetabulum, flexion of the thigh so far as the joint is concerned is practically unlimited. Flexion is the most important, most frequent, and most extensive movement, and in the dissected limb, before the ligaments are disturbed, can be carried to 160°, and is then checked by the lower fibres of the ischio-capsular ligament. In the living subject simple flexion can continue until checked by the contact of the soft parts at the groin, if the knee be bent; if the knee be straight, flexion of the hip is checked in most persons by the hamstring muscles at nearly a right angle. This is very evident on trying to touch the ground with the fingers without bending the knees, the chief strain being felt at the popliteal space. This is due to the shortness of the hamstrings. Extension is limited by the ilio-femoral ligament.

FIG. 314.—LIGAMENTUM TERES, VERY LAX IN COMPLETE EXTENSION.

Abduction and lateral rotation can be performed freely in every position of flexion and extension—abduction being limited by the pubo-capsular ligament; lateral rotation by the ilio-femoral ligament, especially its medial portion, during extension; but by the lateral portion, as well as by the ligamentum teres, during flexion.

Adduction is very limited in the extended thigh on account of the contact with the opposite limb. In the slightly flexed position adduction is more free than in extension, and is then limited by the lateral fibres of the ilio-femoral band and the superior portion of the capsule. In flexion the range is still greater, and limited by the ischio-capsular ligament, the ligamentum teres being also rendered nearly tight. Medial rotation in the extended position is limited by the lower fibres of the ilio-femoral ligament; and in flexion by the ischio-capsular ligament and the portion of the capsule between it and the ilio-femoral band.

The ilio-femoral band also prevents the tendency of the trunk to roll backward on the thigh bones in the erect posture, and so does away with the necessity for muscular power for this purpose; it is put on stretch in the stand-at-ease position.

The ligamentum teres is of little use in resisting violence or in imparting strength to the joint. It assists in checking lateral rotation, and adduction during flexion. A ligament can only be of use when it is tight, and it was found by trephining the bottom of the acetabulum, removing the fat, and threading a piece of whipcord round the ligament, that the ligament was slack in simple flexion, and very loose in complete extension, but that its most slack condition was in abduction. It is tightest in flexion combined with adduction and lateral rotation and almost as tight in flexion with lateral rotation alone, and in flexion with adduction alone (figs. 313–315).

Muscles which act upon the hip-joint.—*Flexors.*—The psoas and iliacus, the rectus femoris, the pectineus, the adductors, the sartorius, the tensor fasciæ latæ, and the gluteus medius.

FIG. 315.—LIGAMENTUM TERES, DRAWN TIGHT IN FLEXION COMBINED WITH LATERAL ROTATION AND ADDUCTION.

Extensors.—The gluteus maximus, the posterior fibres of the glutei medius and minimus, the biceps, the semitendinosus, the semimembranosus, and the ischial fibres of the adductor magnus; also (slightly) the piriformis, obturator internus and gemelli. *Abductors.*—Gluteus maximus (upper fibres), tensor fasciæ latæ, gluteus medius, gluteus minimus, and, when the joint is flexed, the piriformis, obturator internus, the gemelli, and the sartorius also become abductors. *Adductors.*—Adductores magnus, longus, brevis, and minimus, semitendinosus, biceps, the gracilis, the pectineus, the quadratus femoris, and the lower fibres of the gluteus maximus. *Medial rotators.*—Psoas (slightly), adductor magnus, semimembranosus, the anterior fibres of the gluteus medius and minimus, and the tensor fasciæ latæ. *Lateral rotators.*—Gluteus maximus, posterior fibres of gluteus medius and minimus, the adductors, obturator externus, quadratus femoris, obturator internus, the gemelli, and the piriformis when the joint is extended.

2. THE KNEE-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The knee is the largest joint in the body. It is rightly described as a ginglymoid joint, but there is also an arthrodial element; for, in addition to flexion and extension, there is a sliding backward and forward of the tibia upon the femoral condyles, as well as slight rotation round a vertical axis. It is one of the most superficial, and, as far as adaptation of the bony surfaces goes, one of the weakest joints, for in no position are the bones in more than partial contact. Its strength lies in the number, size, and arrangement of the ligaments, and the powerful muscles and fascial expansions which pass over the articulation and enable it to withstand the leverage of the two longest bones in the body. It may be said to consist of two articulations with a common synovial membrane—the patello-femoral and the tibio-femoral, the latter being double. It is composed of the condyles and trochlear surface of the femur, the condyles of the tibia, and the patella, united by the following ligaments, which may be divided into an external and internal set:—

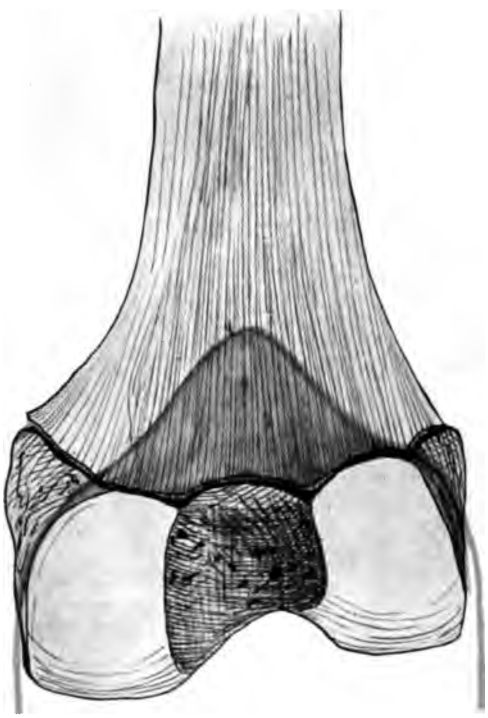
EXTERNAL	INTERNAL
(1) Fibrous expansion of the extensors.	(1) Anterior crucial.
(2) Articular capsule.	(2) Posterior crucial.
(3) Oblique popliteal ligament.	(3) Medial meniscus.
(4) Fibular collateral.	(4) Lateral meniscus.
(5) Tibial collateral.	(5) Coronary.
(6) Ligamentum patellæ	(6) Transverse.

External Ligaments

Superficial to the fibrous expansion of the quadriceps extensor tendons the *fascia lata* of the thigh covers the front and sides of the knee-joint.

The deep fascia of the thigh, as it descends to its attachment to the tuberosity and oblique lines of the tibia, not only overlies but blends with the fibrous expansion of the extensor tendons. The oblique lines of the tibia curve upward and backward from the tuberosity on each side to the postero-lateral part of the condyles. The process of fascia attached to the lateral ridge of the tibia and to the head of the fibula descends from the tensor fasciæ latæ and is very thick and strong. It is firmly blended with the tendinous fibres of the vastus lateralis. The fascia lata, on the medial side of the patella, besides being attached to the medial oblique ridge of the tibia, sends some longitudinal fibres lower down to become blended with the fibrous expansion of the sartorius. The fascia is much thinner on the medial side of the patella than on the lateral, and blends much less with the tendon of the vastus medialis than the lateral part of the fascia does with the vastus lateralis. A thin layer of the fascia lata in the form of transverse or arciform fibres passes over the front of the joint. These fibres are specially well marked over the ligamentum patellæ, and blend here with the central portion of the quadriceps extensor fibres.

Fig. 316.—The Lower Extremity of the Femur (Posterior View), to show the Relation of the Articular Capsule of the Knee-joint (in red) to the Epiphysial Line.



The **fibrous expansion of the extensor tendons** consists—(1) of a central portion, densely thick and strong, 3.7 cm. (1½ in.) broad, which is inserted into the anterior two-thirds of the upper border of the patella, many of its superficial fibres passing over the subcutaneous surface of the bone into the ligamentum patellæ; (2) of two side portions thinner, but strong.

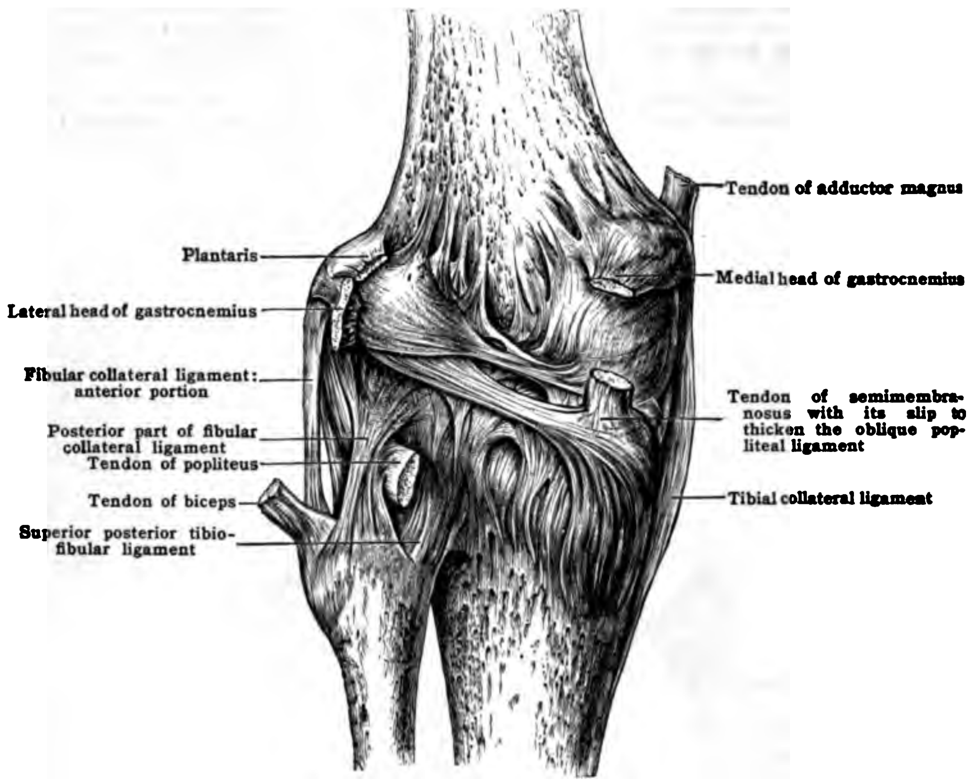
The side portions are inserted into the patella along its upper border on either side of the central portion and also into its medial and lateral borders, nearer the anterior than the posterior surface, as low down as the attachment of the ligamentum patellæ; passing thence along the sides of the ligamentum patellæ to the tibia, they are attached to the oblique lines which extend from the tuberosity to the medial and lateral condyles, and reach as far as the tibial and fibular collateral ligaments. On the lateral side, the fibres blend with the ilio-tibial band of the fascia lata, and on the medial they extend below the oblique line to blend with the periosteum of the shaft. Thus there is a large hood spread over the whole of the front of the joint, investing the patella, and reaching from the sides of the ligamentum patellæ to the collateral ligaments, attached below to the tibia, and separated everywhere from the synovial membrane by a layer of fatty tissue.

The **ligamentum patellæ** (fig. 320) is the continuation in line of the central portion of the conjoined tendon, some fibres of which are prolonged over the front

of the patella into the ligament. It is an extremely strong, flat band, attached above to the lower border of the patella; below, it is fixed to the lower part of the tuberosity and upper part of the crest of the tibia, somewhat obliquely, being prolonged downward further on the lateral side, so that this border is fully 2.5 cm. (1 in.) longer than the medial, which measures 6.7 cm. (2½ in.) in length. Behind, it is in contact with a mass of fat which separates it from the synovial membrane, and a small bursa intervenes between it and the head of the tibia. In front, a large bursa separates it from the subcutaneous tissue, and at the sides it is continuous with the fibrous expansion of the extensors.

The **tibial** (internal) **collateral ligament** (fig. 317) is a strong, flat band, which extends from the depression on the tubercle on the medial side of the medial

FIG. 317.—POSTERIOR VIEW OF THE KNEE-JOINT.



epicondyle of the femur, to the medial border and medial surface of the shaft of the tibia, 3.7 cm. (1½ in.) below the condyle. It is 8.7 cm. (3½ in.) long, well defined anteriorly, where it blends with the expansion of the conjoined extensor tendons; but not so well defined posteriorly, where it merges into the oblique popliteal ligament.

Some of the lower fibres blend with the descending portion of the *semimembranosus* tendon, Its deep surface is firmly adherent to the edge of the medial meniscus and coronary ligament. while part of the *semimembranosus tendon* and *inferior medial articular vessels* and *nerve* pass between it and the bone. Superficially, a bursa separates it from the tendons of the *gracilis* and *semitendinosus* muscles and from the aponeurosis of the *sartorius* muscle.

The **fibular** (external) **collateral ligament** (fig. 317) consists of two portions: the **anterior,** which is the longer and better marked, is a strong, rounded cord, about 5 cm. (2 in.) long, attached above to the tubercle on the lateral side of the lateral epicondyle of the femur, just below and in front of the origin of the lateral head of the *gastrocnemius*, whilst the *tendon* of the *popliteus* arises from the groove below and in front of it. Below, it is fixed to the middle of the lateral surface of the head of the fibula, 1.25 cm.(½) in. or more anterior to the apex.

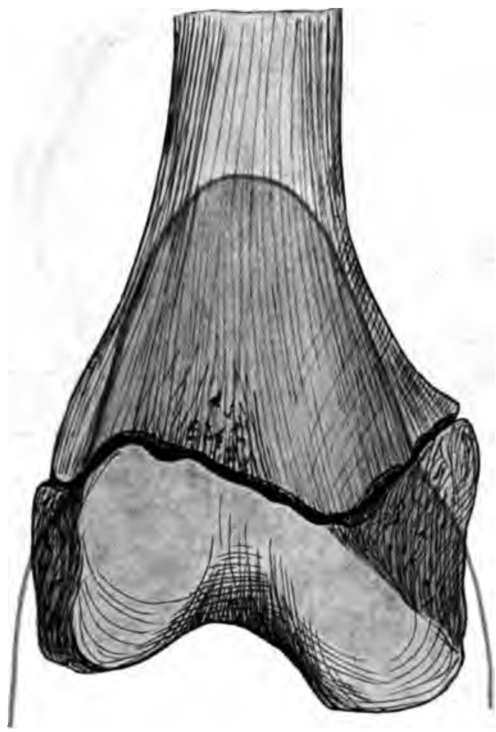
Superficially is the tendon of the *biceps*, which splits to embrace its lower extremity; while beneath it pass the *popliteus tendon* in its sheath, and the *inferior lateral articular vessels* and *nerve*.

Some fibres of the peroneus longus occasionally arise from the lower end of the ligament. The posterior portion is 8 mm. (⅓ in.) behind the anterior. It is broader and less defined; fixed below to the apex of the fibula, it inclines upward and somewhat backward, and ties down the *popliteus* against the lateral condyle of the tibia, blending beneath the lateral head of the *gastrocnemius* with the oblique popliteal ligament of the knee, of which it is really a portion.

The **oblique popliteal ligament** or ligamentum Winslowii (fig. 317) is a broad dense structure of interlacing fibres, with large orifices for vessels and nerves. It is attached above to the femur close to the articular margins of the condyles, stretching across the upper margin of the intercondyloid fossa, to which it is connected by fibro-fatty tissue; it thus reaches across from the tibial to the fibular collateral ligaments. Below, it is fixed to the border of the lateral condyle of the tibia, to the bone just below the posterior intercondyloid notch, and to the shaft of the tibia below the medial condyle, blending with the descending slip of the *semimembranosus* and tibial collateral ligament.

Superficially, an oblique fasciculus from the *semimembranosus* runs across the centre, passing upward and laterally from near the back part of the medial condyle of the tibia to the lateral

FIG. 318.—THE LOWER EXTREMITY OF THE FEMUR (ANTERIOR VIEW) TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE KNEE-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



epicondyle of the femur, where it joins the lateral head of the gastrocnemius, a sesamoid plate being sometimes developed at the point of junction. This slip greatly strengthens the oblique popliteal ligament, of which, if not the chief constituent, it is at least a very important part.

Its deep surface is closely connected with the semilunar menisci (especially the medial) and coronary ligaments, and in the interval between the cartilages with the posterior crucial ligament and fibro-fatty tissue within the joint. Superficially it forms part of the floor of the popliteal space. A special band, the arcuate ligament, is sometimes found extending from the lateral epicondyle to the oblique ligament.

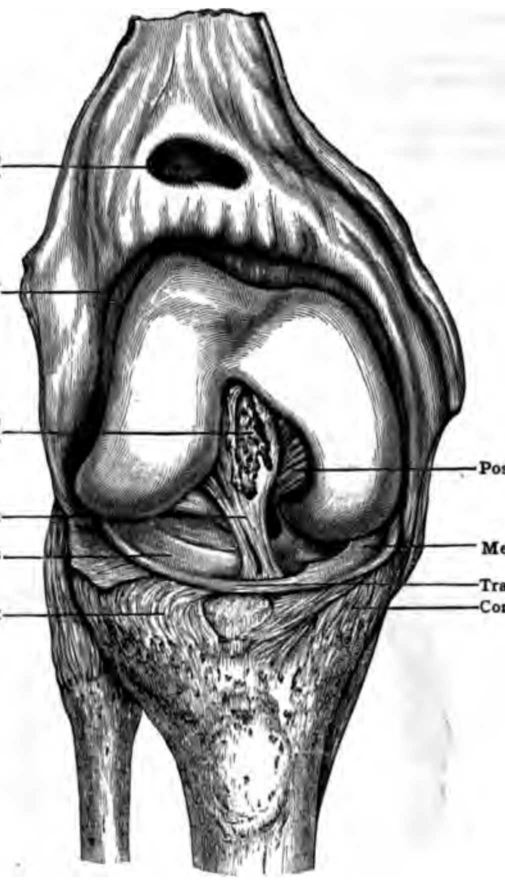
The **articular capsule** (fig. 319) is thin but strong, covering the synovial membrane, and looking like a loose sac. It is attached to the femur near the articular margin on the medial side, but further away on the lateral; it passes beneath the fibular collateral ligament to join the sheath of the *popliteus*. Medially it joins the tibial collateral ligament. Below, it is fixed to the upper as well as the medial and lateral borders of the patella and the anterior border of the head of the tibia. It is strengthened superficially between the femur and patella by an expansion from the *articularis genu* (*sub-crureus*) and is separated from

the fibrous expansion of the extensor tendon by a layer of fatty tissue. The synovial membrane lines its deep surface, and holds it against the borders of the semilunar menisci; it is also attached to the coronary ligaments.

Internal Ligaments

The **anterior crucial ligament** (figs. 319 and 320) is strong and cord-like. It is attached to the medial half of the fossa in front of the intercondyloid eminence of the tibia, and to the lateral border of the medial articular facet as far back as the medial intercondyloid tubercle. It passes upward, backward, and laterally to the back part of the medial surface of the lateral condyle of the femur. To

Fig. 319.—Anterior View of the Internal Ligaments of the Knee-joint.



the tibia, it is fixed behind the anterior extremity of the medial semilunar meniscus. Behind and to the lateral side it has the anterior extremity of the lateral meniscus, a few fibres of which blend with the lateral edge of the ligament.

Its anterior fibres at the tibial end are strongest and longest, being fixed highest on the femur; while the posterior, springing from the intercondyloid eminence, are shorter and more oblique. Near the spine, a slip is sometimes given off to the posterior crucial ligament.

The **posterior crucial ligament** (fig. 319, 320, and 322) is stronger and less oblique than the anterior. It is fixed below to the greater portion of the fossa behind the intercondyloid eminence of the tibia, especially the lateral and posterior portion, and then medially along the posterior intercondyloid fossa; being joined by fibres which arise between the intercondyloid tubercles, it ascends to the anterior part of the lateral surface of the medial condyle of the femur, having a wide crescentic attachment 1.5 cm. ($\frac{3}{5}$ in.) in extent just above the articular surface.

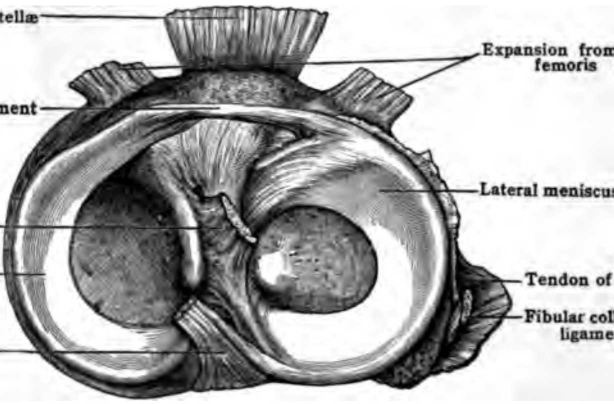
Behind, it is connected at the tibia directly with the posterior ligament, and a little higher up by means of a quantity of interposed areolar tissue. In front it rests upon the posterior

horn of the medial semilunar meniscus, and receives a large slip from the lateral meniscus, which ascends along it, either in front or behind, to the femur; higher up in front it is connected with the anterior crucial ligament.

Until they rise above the intercondyloid eminence of the tibia the two crucial ligaments are closely bound together, so that no interspace exists between their tibial attachments and the point of decussation; the only space between them is therefore a V-shaped one corresponding to the upper half of their X-shaped arrangement, and this is a mere chink in the undissected state, and can be seen from the front only, owing to the fatty tissue beneath the synovial membrane which surrounds their femoral attachment.

The interarticular **menisci** or semilunar fibro-cartilages (figs. 319 and 320) are two crescentic discs resting upon the circumferential portions of the articular facets of the tibia, and moving with the tibia upon the femur. They somewhat deepen the tibial articular surfaces, and are dense and compact in structure, becoming looser and more fibrous near their extremities, where they are firmly fixed in front of and behind the intercondyloid eminence of the tibia. The circumferential border of each is convex, thick, and somewhat loosely attached to the borders of the condyles of the tibia by the coronary ligaments and the reflexion of the synovial membrane. The inner border is concave, thin, and free. Half an inch (1.3 cm.) broad at the widest part, they taper somewhat toward their

FIG. 320.—STRUCTURES LYING ON THE HEAD OF THE TIBIA. (Right knee.)



extremities, and cover rather less than two-thirds of the articular facets of the tibia. Their upper surfaces are slightly concave, and fit on to the femoral condyles, while the lower are flat and rest on the head of the tibia; both surfaces are smooth and covered by synovial membrane.

The **lateral meniscus** (fig. 320) is nearly circular in form and less firmly fixed than the medial, and consequently slides more freely upon the tibia. Its anterior cornu is attached to a narrow depression along the lateral articular facet, just in front of the lateral intercondyloid tubercle of the tibia, close to, and on the lateral side of, the anterior crucial ligament; a small slip from the cornu is often fixed to the tibia in front of the crucial ligament. The posterior cornu is firmly attached to the tibia behind the lateral intercondyloid tubercle, blending with the posterior crucial ligament, and giving off a well-marked fasciculus, which runs up along the anterior border of the ligament to be attached to the femur (ligament of Wrisberg). It also sends a narrow slip into the back part of the anterior crucial ligament. Its outer border is grooved toward its posterior part by the *popliteus* tendon, which is held to it by fibrous tissue and synovial membrane, and separates it from the fibular collateral ligament. From its anterior border is given off the transverse ligament.

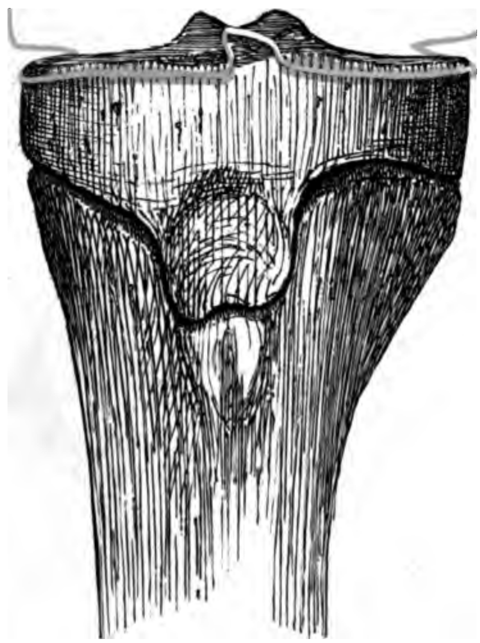
The **medial meniscus** (fig. 320) is a segment of a larger circle than the lateral, and has an outline more oval than circular. Its anterior cornu is wide, and has a broad and oblique attachment to the anterior margin of the head of the tibia. It reaches from the margin of the condyle toward the middle of the fossa in front of the intercondyloid eminence, being altogether in front of the anterior crucial ligament. The posterior cornu is firmly fixed by a broad insertion in an antero-posterior line along the medial side of the posterior intercondyloid fossa, from the medial tubercle to the posterior margin of the head of the tibia. Its convex border is connected with the tibial collateral ligament and the *semimembranosus* tendon.

The **transverse ligament** (figs. 319 and 320) is a rounded, slender, short cord, which extends from the convex border of the lateral meniscus to the concave border or anterior cornu of the medial, near which it is sometimes attached to the bone. It is an accessory band of the lateral meniscus, and is situated beneath the synovial membrane.

The **coronary ligaments** (fig. 319) connect the margins of the semilunar discs with the head of the tibia. The lateral is much more lax than the medial, permitting the lateral disc to change its position more freely than the medial. They are not in reality separate structures, but consist of fibres of the several surrounding ligaments of the knee-joint which become attached to the margins of the discs as they pass over them.

The **synovial membrane** (fig. 324) of the knee forms the largest synovial sac in the body. Bulging upward from the patella, it follows the capsule of the joint into a large *cul-de-sac* beneath the tendon of the extensor muscles on the front of the femur. It reaches some distance beyond the articular surface of the bone, and communicates very frequently with a large bursa interposed between the tendon and the femur above the line of attachment of the articular capsule. After investing the circumference of the lower end of the femur, it is reflected upon the

Fig. 321.—The Upper Extremity of the Tibia (Anterior View), to show the Relation of the Articular Capsule of the Knee-joint (in red) to the Epiphysial Line.



fibrous envelope of the joint formed by the capsular, posterior, and collateral ligaments.

The synovial membrane covers a great portion of the crucial ligaments, but leaves uncovered the back of the posterior crucial where the latter is connected with the posterior ligament, and the lower part of both crucial ligaments where they are united. Thus the ligaments are completely shut out of the synovial cavity. Along the fibrous envelope the synovial membrane is conducted down to the semilunar menisci, over both surfaces of which it passes, and is reflected off the under surface on to the coronary ligaments, and thence down to the head of the tibia, around the circumference of which it extends a short way. It dips down between the external meniscus and the head of the tibia as low as the superior tibio-fibular ligament, reaching inward nearly as far as the intercondyloid notch, and forming a bursa for the play of the popliteal tendon.

At the back of the joint two pouches are prolonged beneath the muscles, one on each side between the condyle of the femur and the origin of the gastrocnemius. Large processes of synovial membrane also project into the joint, and being occupied by fat serve as padding to fill up spaces. The chief of these processes, the patellar synovial fold (ligamentum mucosum) (figs. 322 and 324), springs from the infrapatellar fatty mass. This so-called ligament is the central portion of the large process of synovial membrane, of which the alar folds form the free margins. It extends from the fatty mass, below the patella, backward and upward to the intercondyloid notch of the femur, where it is attached in front of the anterior crucial, and lateral to the posterior crucial ligament. Near the femur it is thin and transparent, consisting of a double fold of synovial membrane, but near the patella it contains some fatty tissue. Its anterior or upper edge is free, and fully 2.5 cm. (an inch) long; the posterior or lower edge is half the length, and *is attached to the* crucial ligaments above, but is free below.

Passing backward from the capsule on each side of the patella is a prominent crescentic fold formed by reduplications of the synovial membrane—these are the **alar folds** (fig. 322). Their free margins are concave and thin, and are lost below in the patellar fold. There is a slight fossa above and another below each ligament.

FIG. 322.—ANTERIOR VIEW OF THE KNEE-JOINT, SHOWING THE SYNOVIAL LIGAMENTS. (Anterior portion of capsule with the extensor tendon thrown downward.)

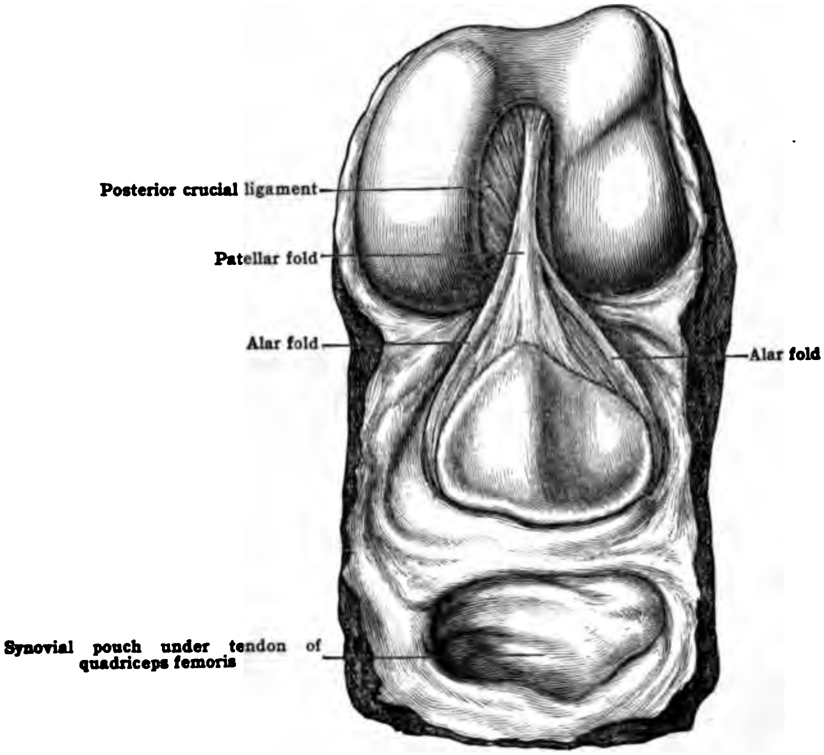
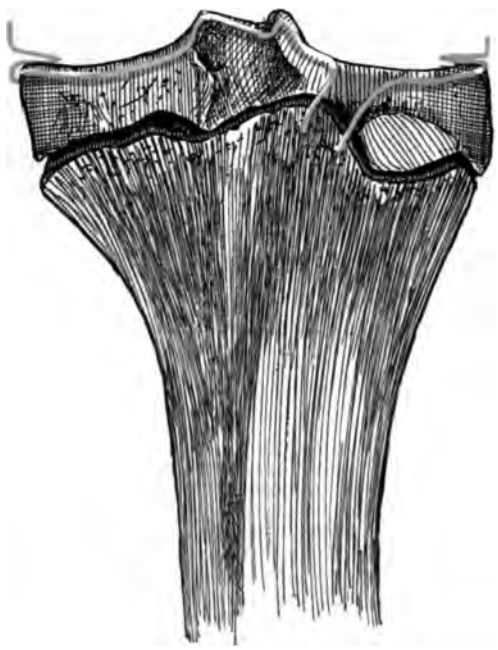


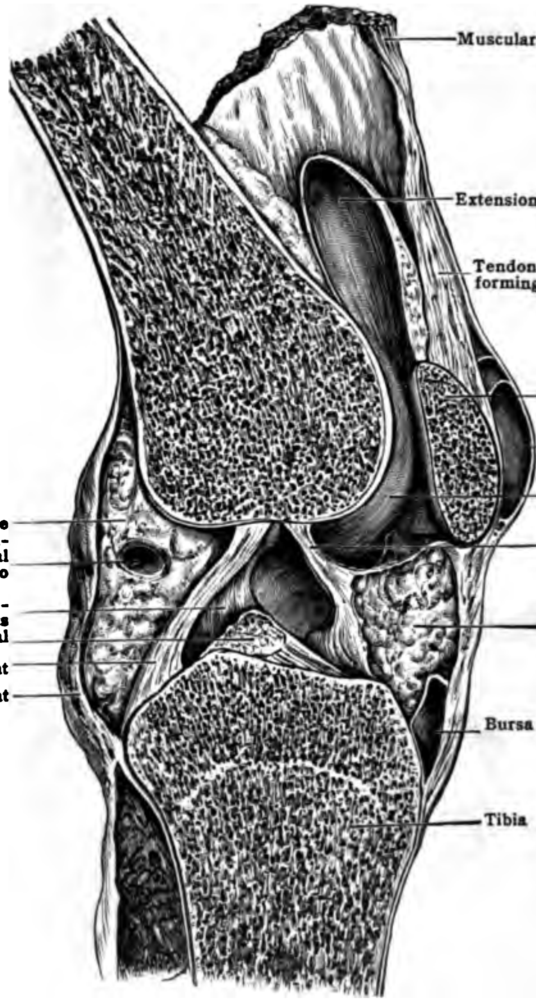
FIG. 323.—THE UPPER EXTREMITY OF THE TIBIA (POSTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE KNEE-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



The **arterial supply** is derived from the art. genu suprema (anastomotica); the superior and inferior medial and lateral articular; the medial articular; the descending branch of the lateral circumflex; the *anterior* recurrent branch from the anterior tibial; and the posterior tibial *recurrent.*

The **nerve-supply** comes from the great sciatic, femoral, and obturator sources. The **great sciatic** gives off the tibial and common peroneal; the tibial sends two, sometimes three branches—one with the medial articular artery; one with the inferior medial, and sometimes one with the superior medial articular artery; the common peroneal gives a branch which accompanies the superior, and another which accompanies the inferior articular artery, and a recurrent branch which follows the course of the anterior recurrent branch of the anterior tibial artery. The **femoral** sends an articular branch from the nerve to the vastus lateralis; a second from the nerve to the vastus medialis; and sometimes a third from that to the vastus intermedius. Thus there are three articular twigs to the knee derived from the muscular branches of the femoral. The **obturator** by its deep division sends a branch through the adductor magnus on to the popliteal artery, which enters the joint posteriorly.

FIG. 324.—SAGITTAL SECTION OF THE KNEE-JOINT.
(The bones are somewhat drawn apart.)



Relations.—Anteriorly and at the sides the knee-joint is merely covered and protected by skin, fascia, and the tendinous expansions of the quadriceps extensor muscle. Laterally and posteriorly it is crossed by the biceps tendon. Medially and posteriorly lie the sartorius and the tendons of the gracilis and semitendinosus muscles. Posteriorly it is in relation with the popliteal vessels and nerves, the semimembranosus, the two heads of the gastrocnemius, and the plantaris. The tendon of the popliteus pierces the capsule behind and medial to the biceps tendon.

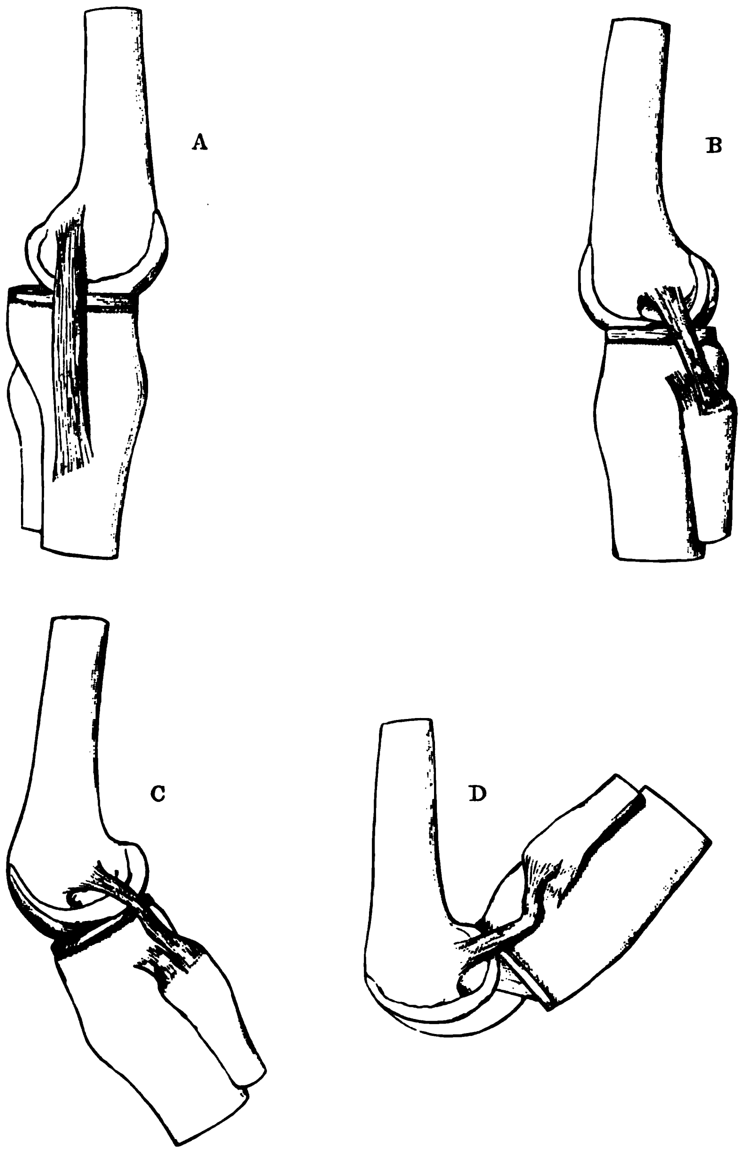
The **movements** which occur at the knee-joint are flexion and extension, with some slight amount of rotation in the bent position. These movements are not so simple as the corresponding ones at the elbow, for the knee is not a simple hinge joint. The movements of rotation instead of occurring between tibia and fibula, as between radius and ulna, are movements of the tibia with the fibula upon the condyles of the femur.

The knee differs from a true hinge joint, like the elbow or ankle, in the following particulars:—

1. *The points of contact of the femur with the tibia are constantly changing.* Thus, in

the flexed position, the posterior part of the articular surface of the tibia is in contact with the rounded back part of the femoral condyles; in the semiflexed position the middle parts of the tibial facets articulate with the anterior rounded part of the condyles; while in the fully extended position the anterior and middle parts of the tibial facets are in contact with the anterior flattened portion of the condyles. So with the patella: in extreme flexion the medial articular facet rests on the lateral part of the medial condyle of the femur; in flexion the upper pair of facets rests on the lower part of the trochlear surface of the femur; in mid-flexion the middle pair rests on the middle of the trochlear surface; while in extension the lower pair of facets on the patella rests on the upper portion of the trochlear surface of the femur.

Fig. 325.—The Collateral Ligaments of the Knee in Flexion and Extension.



This difference may be described as the shifting of the points of contact of the articular surface.

2. It differs from a true hinge in that, in passing from a state of extension to one of flexion, the tibia does not revolve round a single transverse axis drawn through the lower end of the femur, as the ulna does round the lower end of the humerus. The articular surface of the tibia slides forward in extension and backward in flexion; thus the axis round which the tibia revolves upon the femur is a shifting one, as is seen by reference to fig. 325, B, C, D.

3. Another point of difference is that extension is accompanied by lateral rotation, and flexion by medial rotation. This rotation occurs round a vertical axis drawn through the middle of the lateral condyle of the femur and the lateral condyle of the tibia, and is most marked at the termination of extension and at the commencement of flexion. This rotation of the leg at the knee is a true rotation about a vertical axis, and thus differs from the obliquity of the flexion

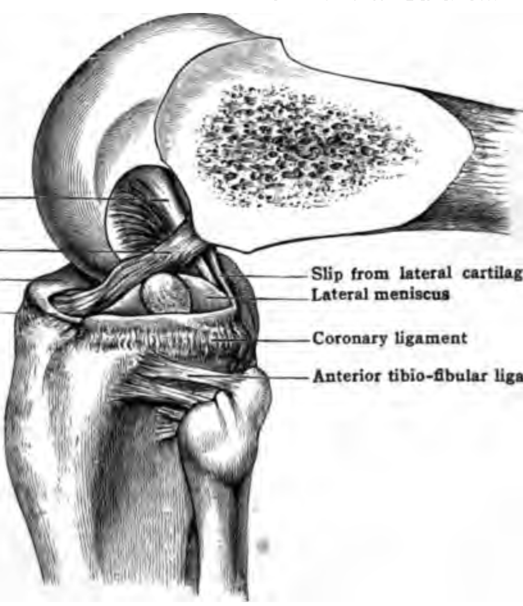
and extension movements at the elbow which is due to the oblique direction of the articular surfaces of the bones.

4. The antero-posterior spiral curve of the femoral condyles is such that the anterior part is an arc of a greater circle than the posterior; hence certain ligaments which are tightened during

FIG. 326.—SECTION OF KNEE, SHOWING CRUCIAL LIGAMENTS IN EXTENSION.

extension are relaxed during flexion, and thereby a considerable amount of rotatory movement is permitted in the flexed position. The axis of this rotation is vertical, and passes through the medial intercondyloid tubercle of the tibia, so that the lateral condyle moves in the arc of a larger circle than does the medial, and is therefore required to move more freely and easily;

FIG. 327.—CRUCIAL LIGAMENTS IN FLEXION.



hence the shape of the lateral articular facet and the loose connection of the lateral meniscus which is adapted to it.

In **extension**, all the ligaments are on the stretch with the exception of the ligamentum patellæ and front of the capsule. Extension is checked by both the crucial ligaments and the *collateral ligaments* (figs. 325, A, B, and 326).

In **flexion** the ligamentum patellæ and anterior portion of the capsule are on the stretch; so also is the posterior crucial in extreme flexion, though it is not quite tight in the semiflexed state of the joint. All the other ligaments are relaxed (fig. 325, C, D), although the relaxation of the anterior crucial ligament is slight in extreme flexion (fig. 327). Flexion is only checked during life by the contact of the soft parts, i. e., the calf with the back of the thigh.

Rotation medially is checked by the anterior crucial ligament; the collateral ligaments being loose.

Rotation laterally is checked by the collateral ligaments; the crucial ligaments have no controlling effect on it, as they are untwisted by it.

Sliding movements are checked by the crucial and collateral ligaments—sliding forward especially by the anterior, and sliding backward by the posterior crucial.

Muscles which act upon the knee-joint.—*Flexors.*—Biceps, semimembranosus, semitendinosus, sartorius, gastrocnemius, plantaris, and popliteus. *Extensor.*—Quadriceps extensor. **Medial** *Rotators.*—Sartorius, gracilis, semitendinosus, semimembranosus, popliteus. **Lateral** *Rotator.*—Biceps.

3. THE TIBIO-FIBULAR UNION

The fibula is connected with the tibia throughout its length by an interosseous membrane, and at the upper and lower extremities by means of two joints. Very little movement is permitted between the two bones.

(*a*) The **superior tibio-fibular joint.**
(*b*) The **middle tibio-fibular union.**
(*c*) The **inferior tibio-fibular joint.**

(*a*) The Superior Tibio-fibular Joint

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The superior tibio-fibular joint is about 6 mm.(¼ in.) below, and quite distinct from, the knee at its upper and anterior part; but at its posterior and superior aspect, where the border of the lateral condyle of the tibia is bevelled by the popliteus muscle, the joint is in the closest proximity to the bursa beneath the tendon of that muscle, and is only separated from the knee-joint by a thin septum of areolar tissue. There is often a communication between the synovial cavities of the two joints. The ligaments uniting the bones are:—

Articular capsule. Anterior tibio-fibular.
Posterior tibio-fibular.

The **articular capsule** is a well-marked fibro-areolar structure; it is attached close round the articular margins of the tibia and fibula. In front it is shut off completely from the knee-joint by the capsule of the knee and the coronary ligament; but behind, it is often very thin, and may communicate with the bursa under the popliteus tendon.

The **anterior tibio-fibular (capitular) ligament** (fig. 326) consists of a few fibres which pass upward and medially from the fibula to the tibia. It lies beneath the anterior portion of the tendon of the biceps.

The **posterior tibio-fibular (capitular) ligament** (fig. 317) consists of a few fibres which pass upward and medially between the adjacent bones, from the head of the fibula to the lateral condyle of the tibia.

The **superior interosseous ligament** consists of a mass of dense yellow fibroareolar tissue, binding the opposed surfaces of the bones together for 2 cm. (¾ in.) below the articular facets. It is continuous with the interosseous membrane along the tibia.

The **biceps tendon** is divided by the fibular collateral ligament of the knee; of the two divisions the anterior is by far the stronger, and is inserted into the lateral condyle of the tibia as well as to the front of the head of the fibula, and thus the muscle, acting on both bones, tends to brace them more tightly together; indeed, it holds the bones strongly together after all other connections have been severed.

The **synovial membrane** which lines the joint sometimes communicates with the knee-joint through the bursa beneath the popliteus tendon.

The **arterial supply** is from the inferior lateral articular and recurrent tibial arteries.

The **nerve-supply** is from the inferior lateral articular, and also from the recurrent branch of the common peroneal.

Relations.—In front, the upper ends of the tibialis anterior, the extensor digitorum longus, and the peroneus longus. Behind, the tendon of the popliteus overlapped by the lateral head of the gastrocnemius. Laterally, the biceps tendon and the common peroneal nerve. Below and medially, the anterior tibial vessels.

The **movements** are but slight, and consist merely of a gliding of the two bones upon each other. The joint is so constructed that the fibula gives some support to the tibia in transmitting

the weight to the foot. The articular facet of the tibia overhangs, and is received upon the articular facet of the head of the fibula in an oblique plane. This joint allows of slight yielding of the lateral malleolus during flexion and extension of the ankle-joint, the whole fibula gliding slightly upward in flexion, and downward in extension, of the ankle.

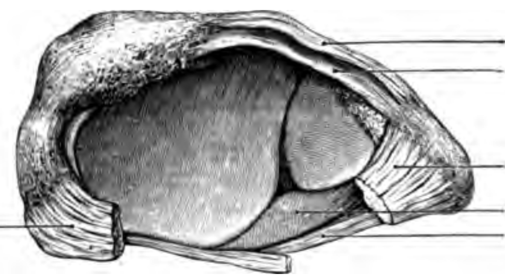
(b) The Middle Tibio-fibular Union

Class.—*Synarthrosis.* **Subdivision.**—*Syndesmosis.*

The **interosseous membrane** is attached along the lateral border of the tibia and the interosseous border of the fibula. It is deficient above for about 2.5 cm. (1 in.) or more, measured from the under aspect of the superior joint. Its upper border is concave, and over it pass the anterior tibial vessels.

The membrane consists of a thin aponeurotic and translucent lamina, formed of oblique fine fibres, some of which run from the tibia to the fibula, and some from the fibula to the tibia, but all are inclined downward. They are best marked at their attachment to the bones, and gradually grow denser and thicker as they approach the inferior interosseous ligament. The

Fig. 328.—Lower Ends of Left Tibia and Fibula, showing the Ligaments. The synovial fold between these bones has been removed to show the transverse ligament forming part of the capsule of the joint, and the deeper fibres of the anterior lateral malleolar ligament which come into contact with the talus.
(From a dissection by Mr. W. Pearson, of the Royal College of Surgeons' Museum.)



chief use of the membrane is to afford a surface for the origin of muscles. It is continuous below with the inferior interosseous ligament.

In front of the interosseous membrane lie the tibialis anterior, the extensor digitorum longus, the extensor hallucis longus, and the anterior tibial vessels and nerves. Behind it is in relation with the tibialis posterior, the flexor hallucis longus, and the peroneal artery.

(c) The Inferior Tibio-fibular Articulation

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

This junction is formed by the lower ends of the tibia and fibula. The rough triangular surface on each of these bones formed by the bifurcation of their interosseous lines is closely and firmly united by the inferior interosseous ligament. The fibula is in actual contact with the tibia by an articular facet, which is small in size, crescentic in shape, and continuous with the articular facet of the malleolus.

The ligaments which unite the bones are:—

1. Anterior lateral malleolar ligament.
2. Posterior lateral malleolar ligament.
3. Transverse ligament.
4. Inferior interosseous ligament.

The **anterior lateral malleolar ligament** (anterior inferior tibio-fibular ligament) (figs. 328 and 334) is a strong triangular band about 2 cm. ($\frac{3}{4}$ in.) wide, and is attached to the lower extremity of the tibia at its anterior and lateral angle, close to the margin of the facet for the talus and passes downward and

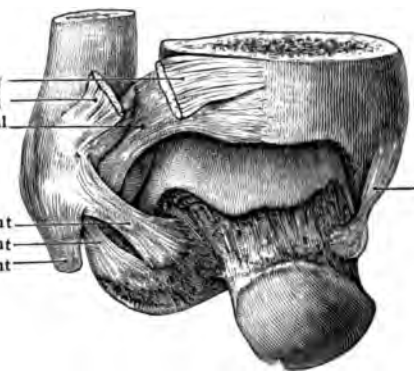
laterally to the anterior border and contiguous surface of the lower end of the fibula, some fibres passing along the edge nearly as far as the origin of the anterior talo-fibular ligament.

The fibres increase in length from above downward. In front it is in relation with the *peroneus tertius* and deep fascia of the leg, and gives origin to fibres of the anterior ligament of the ankle-joint. Behind, it lies in contact with the interosseous ligament, and comes into contact with the articular surface of the talus (see figs. 328 and 329).

The **posterior lateral malleolar ligament** (figs. 328 and 334) is very similar to the anterior, extending from the posterior and lateral angle of the lower end of the tibia downward and laterally to the lowest 1.5 cm. (½ in.) of the border separating the medial from the posterior surface of the shaft of the fibula, and to the upper part of the posterior border of the lateral malleolus. It is in relation in front with the interosseous ligament; below, it touches the transverse ligament.

The **inferior interosseous ligament** is a dense mass of short, felt-like fibres, passing transversely between and firmly uniting the opposed rough triangular surfaces at the lower ends of the

FIG. 329.—RIGHT ANKLE-JOINT, SHOWING THE LIGAMENTS.
(From dissection by Mr. W. Pearson, of the Royal College of Surgeons' Museum.)



tibia and fibula, except for 1 cm. (⅜ in.) at the extremity, where there is a synovial cavity. It extends from the anterior to the posterior lateral malleolar ligaments, reaching upward 4 cm. (1½ in.) in front, but only half this height behind.

The **transverse ligament** (fig. 331) is a strong rounded band, attached to nearly the whole length of the inferior border of the posterior surface of the tibia, just above the articular facet for the talus. It then inclines a little forward and downward, to be attached to the medial surface of the lateral malleolus, just above the fossa, and into the upper part of the fossa itself.

The **synovial membrane** is continuous with that of the ankle-joint; it projects upward between the bones beyond their articular facets as high as the inferior interosseous ligament.

The **nerve-supply** is the same as that of the ankle-joint; the **arterial** supply is from the peroneal and the anterior peroneal, and sometimes from the anterior tibial, or its lateral malleolar branch.

Relations.—In front of the inferior tibio-fibular joint are the anterior peroneal artery and the tendon of the peroneus tertius, and behind it are the posterior peroneal artery and the pad of fat which lies in front of the tendo Achillis.

The **movement** permitted at this joint is a mere gliding, chiefly in an upward and downward direction, of the fibula on the tibia. The bones are firmly braced together and yet form a slightly yielding arch, thus allowing a slight side to side expansion during extreme flexion, when the broad part of the talus is brought under the arch, by the upward gliding of the fibula on the tibia. To this end the direction of the fibres of the lateral malleolar ligaments is downward from tibia to fibula. This mechanical arrangement secures perfect contact of the articular surfaces of the ankle-joint in all positions of the foot.

4. THE ANKLE-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The ankle [articulatio talo-cruralis] is a perfect ginglymus or hinge joint. The bones which enter into its formation are: the lower extremity and medial malleolus of the tibia, and the lateral malleolus of the fibula, above; and the upper

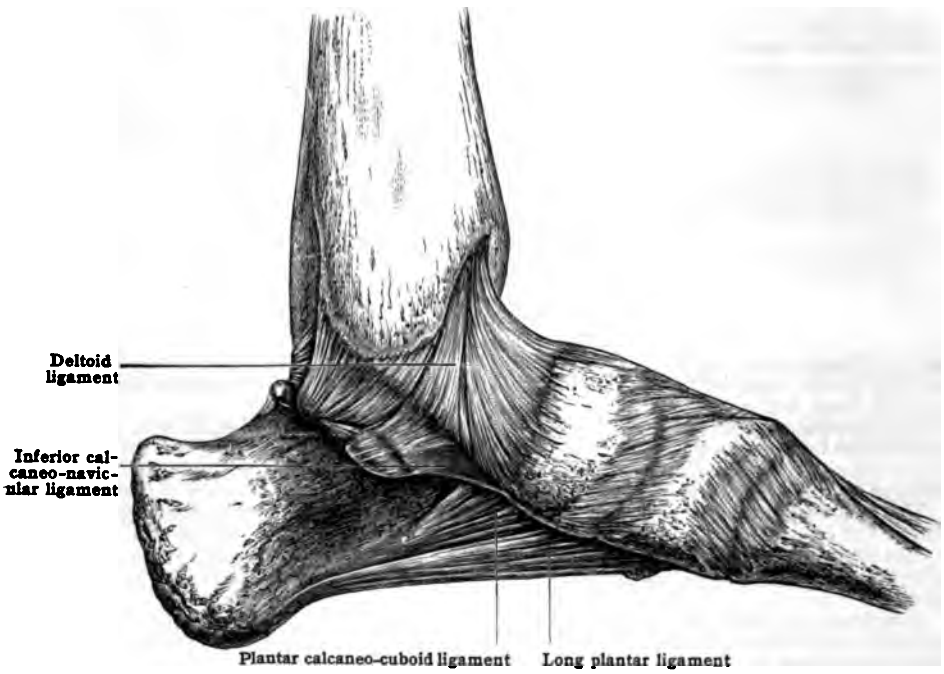
and lateral articular surfaces of the talus (astragalus) below. The ligaments (supplementing the articular capsule) uniting the bones are:—

Anterior.	Deltoid.
Posterior.	Lateral ligament.

The **anterior ligament** (fig. 334) is a thin, membranous structure, which completes the capsule in front of the joint. It is attached above to the anterior border of the medial malleolus, to a crest of bone just above the transverse groove at the lower end of the tibia, to the anterior lateral malleolar ligament, and to the anterior border of the lateral malleolus. Below, it is attached to the rough upper surface of the neck of the talus (astragalus). Medially it is thicker, and is fixed to the talus close to the facet for the medial malleolus, being continuous with the deltoid ligament, and passing forward to blend with the talo-navicular ligament. Laterally it is attached to the talus, just below and in front of the angle between the superior and lateral facets, close to their edges, and joins the anterior talo-fibular ligament.

It is in relation, in front with the *tibialis anterior* muscle, the anterior tibial vessels and nerve, the *extensor tendons of the toes*, and the *peroneus tertius;* and behind with a mass of fat and synovial membrane.

FIG. 330.—MEDIAL VIEW OF THE ANKLE AND THE TARSUS, SHOWING THE GROOVE FOR THE TENDON OF THE TIBIALIS POSTERIOR.



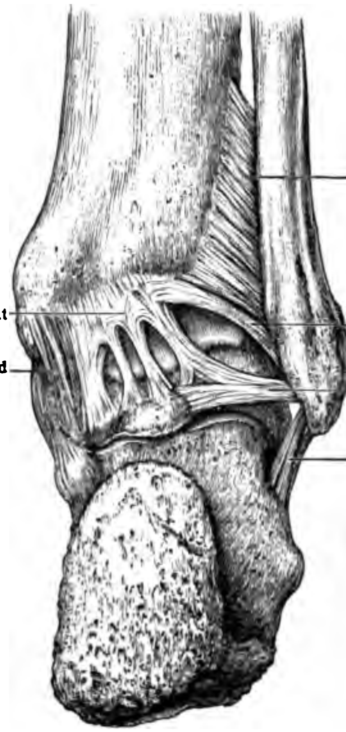
The **posterior ligament** (fig. 331) is a very thin and disconnected membranous structure, connected above with the lateral malleolus, medial to the peroneal groove; to the posterior margin of the lower end of the tibia lateral to the groove for the tibialis posterior; and to the posterior lateral malleolar ligament. Below, it is attached to the posterior surface of the talus from the deltoid to the lateral ligaments. The passage of the flexor hallucis longus tendon over the back of the joint serves the purpose of a much stronger posterior ligament.

The **deltoid ligament** (fig. 330) is attached superiorly to the medial malleolus along its lower border, and to its anterior surface superficial to the anterior ligament; some very strong fibres are fixed to the notch in the lower border of the malleolus, and, getting attachment below to the rough depression on the medial side of the talus, form a **deep** portion to the ligament. The ligament radiates; the posterior fibres are short, and incline a little backward to be fixed to the rough medial surface of the talus, close to the superior articular facet, and into the

tubercle to the medial side of the flexor hallucis longus groove. The fibres next in front are numerous and form a thick and strong mass, filling up the rough depression on the medial surface of the talus, whilst some pass over the talo-calcaneal joint to the upper and medial border of the sustentaculum tali. The fibres which are connected above with the anterior surface of the malleolus pass downward and somewhat forward to be attached to the navicular and to the margin of the calcaneo-navicular ligament.

The **lateral ligament** (figs. 329 and 334) consists of three distinct slips (fasciculi). The **anterior talo-fibular ligament** (anterior fasciculus), is ribbon-like and passes from the anterior border of the lateral malleolus near the tip to the rough surface of the talus in front of the lateral facet, and overhanging the sinus pedis. The **calcaneo-fibular ligament** (middle fasciculus), is a strong roundish bundle, which extends downward and somewhat backward from the anterior border of the lateral malleolus close to the attachment of the anterior fasciculus, and from the lateral surface of the malleolus, just in front of the apex, to a tubercle on the middle of the lateral surface of the calcaneum. The **posterior talo-**

FIG. 331.—LIGAMENTS SEEN FROM THE BACK OF THE ANKLE-JOINT.



fibular ligament (posterior fasciculus), is almost horizontal; it is a strong, thick band attached at one end to the posterior border of the malleolus, and slightly to the fossa on the medial surface; and at the other end to the talus, behind the articular facet for the fibula, as well as to a tubercle on the lateral side of the groove for the *flexor hallucis longus.*

The middle fasciculus is covered by the tendons of the *peronei longus* and *brevis;* and in extension, the posterior fasciculus is received into the pit on the medial surface of the lateral malleolus.

The **synovial membrane** is very extensive. Besides lining the ligaments of the ankle, it extends upward between the tibia and fibula, forming a short *cul-de-sac* as far as the interosseous ligament. Upon the anterior and posterior ligaments it is very loose, and extends beyond the limits of the articulation. It is said to contain more synovia than any other joint.

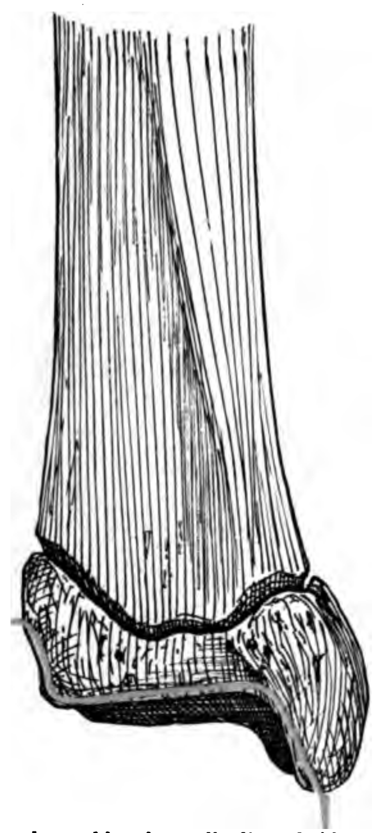
The **nerve-supply** is from the saphenous, posterior tibial, and the lateral division of the anterior tibial.

The **arterial supply** comes from the anterior tibial, the anterior peroneal, the lateral malleolar, the posterior tibial, and posterior peroneal.

Relations.—In front and in contact with the anterior ligament, from medial to lateral aspects, are the tendons of the tibialis anterior, the tendon of the extensor hallucis longus, the anterior tibial vessels, the anterior tibial nerve, the tendons of the extensor digitorum longus, and the tendon of the peroneus tertius. To the medial side of the tibialis anterior and to the lateral side of the peroneus tertius the joint is subcutaneous anteriorly. Behind and laterally are the tendons of the peroneus longus and brevis. Behind and medially, from medial to lateral side, are the tendon of the tibialis posterior, the tendon of the flexor digitorum longus, the posterior tibial vessels, the posterior tibial nerve, and the tendon of the flexor hallucis longus. Directly behind is a pad of fat which intervenes between the tendo Achillis and the joint. Below and on the lateral side, crossing the middle fasciculus of the lateral ligament, are the tendons of the peroneus longus and brevis. Below and on the medial side, crossing the deltoid ligament, are the tendons of the tibialis posterior and the flexor digitorum longus.

Movements.—This being a true hinge joint, flexion and extension are the only movements of which it is capable, there being no side to side motion, except in extreme extension, when the narrowest part of the talus is thrust forward into the widest part of the tibio-fibular arch.

Fig. 332.—The Lower Extremity of the Tibia (Anterior view), to Show the Relation of the Articular Capsule of the Ankle-joint (in red) to the Epiphysial Line.



In flexion the talus is tightly embraced by the malleoli, and side to side movement is impossible. Flexion of the ankle-joint is limited by:—(i) nearly the whole of the fibres of the deltoid ligament, none but the most anterior being relaxed; (ii) the posterior and middle portions of the lateral ligament, especially the posterior; (iii) the posterior ligament of the ankle. It is also limited by the neck of the talus abutting on the edge of the tibia.

In most European ankle-joints the anterior edge of the lower end of the tibia is kept from actual contact with the neck of the talus in positions of extreme flexion by the intervention of a pad of fat situated beneath the anterior extension of the anterior ligament. In races which adopt a squatting posture, however, an actual articulation may be developed between these two bony surfaces, a facet being present both upon the anterior margin of the tibia and upon the neck of the talus. These facets are known as "squatting facets" (fig. 333, A) and are of common occurrence in ancient bones and in the bones of modern oriental people.

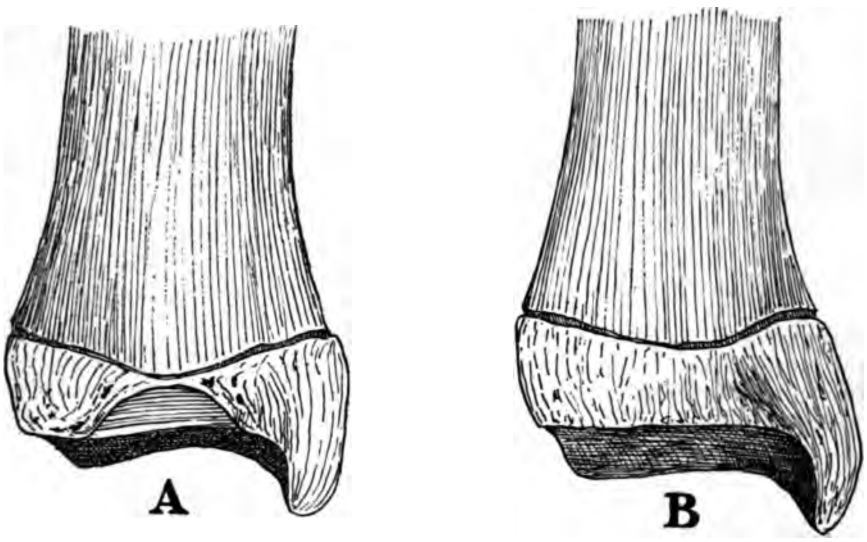
Extension of the ankle-joint is limited by:—(i) the anterior fibres of the deltoid ligament; (ii) the anterior and middle portions of the lateral ligament; (iii) the medial and stronger fibres of the anterior ligament. It is also limited by the posterior portion of the talus meeting with the tibia. Thus the middle portion of the lateral ligament is always on the stretch, owing to its obliquely backward direction, whereby it limits flexion; and its attachment to the fibula in front of the malleolar apex, whereby it prevents over-extension as soon as the foot begins to twist

medialward. This medial twisting, or adduction of the foot, is partly due to the greater posterior length of the medial border of the superior articular surface of the talus, and to the less proportionate height posteriorly of the lateral border of that surface, but chiefly to the side to side movement in the talo-calcaneal joints. Flexion and extension take place round a transverse axis drawn through the body of the talus. The movement is not in a direct antero-posterior plane, but on a plane inclined forward and laterally from the middle of the astragalus to the intermetatarsal joint of the second and third toes.

Muscles which act on the ankle-joint.—*Flexors.*—Tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus tertius. *Extensors.*—Tibialis posterior, flexor digitorum longus, flexor hallucis longus, peroneus longus, peroneus brevis, soleus, gastrocnemius, plantaris.

FIG. 333.—ANTERIOR ASPECT OF THE LOWER EXTREMITY OF THE TIBIA.

In *A*, the articular surface is prolonged upward in front, forming a "squatting facet" which articulates with a corresponding facet on the neck of the talus. In *B* (the usual condition) the articular surface is confined to the lower aspect of the bone.



5. THE TARSAL JOINTS

These may be divided into the following sub-groups:—

(*a*) The **talo-calcaneal union.**
(*b*) The **articulations of the anterior portion of the tarsus.**
(*c*) The **medio-tarsal joint.**

(*a*) THE TALO-CALCANEAL UNION

There are two joints which enter into this union—viz., an anterior and a posterior.

(i) *The Posterior Talo-calcaneal Joint*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The calcaneus articulates with the talus by two joints, the anterior and posterior: the former communicates with the medio-tarsal; the posterior is separate and complete in itself. At the latter joint the two bones are united by an articular capsule with the following ligaments:—

Interosseous. Lateral talo-calcaneal.
Posterior talo-calcaneal. Medial talo-calcaneal.

The **interosseous ligament** (figs. 334 and 335) is a strong band connecting the apposed surfaces of the calcaneus and talus along their oblique grooves. It is composed of several vertical laminæ of fibres, with some fatty tissue in between.

It is better marked, deeper, and broader laterally. Strong laminæ extend from the rough inferior and lateral surfaces of the neck of the talus to the rough superior surface of the calcaneus anteriorly, forming the posterior boundary of the anterior talo-calcaneal joint; these have been described as the **anterior (interosseous) ligament.** The posterior laminæ extend from the roof of the sinus pedis to the calcaneus immediately in front of the lateral facet, thus forming the anterior part of the capsule of the posterior joint.

The **lateral talo-calcaneal ligament** (fig. 334) extends from the groove just below and in front of the lateral articular facet of the talus, to the calcaneus some little distance from the articular margin. Its fibres are nearly parallel with those of the calcaneo-fibular ligament of the ankle, which passes over it and adds to its strength. It fills up the interval between the calcaneo-fibular and anterior talo-fibular ligaments, a considerable bundle of its fibres blending with the anterior border of the calcaneo-fibular.

The **posterior talo-calcaneal ligament** passes from the lateral tubercle of the talus and lower edge of the groove for the flexor hallucis longus to the calcaneus, a variable distance from the articular margin.

The **medial talo-calcaneal ligament** includes two portions. The first is a narrow band of well-marked fibres passing obliquely downward and forward from the medial tubercle of the talus, just behind the medial end of the sinus tarsi, to the calcaneus behind the sustentaculum tali, thus completing the floor of the groove for the flexor hallucis longus tendon. The second portion, which is often considered a separate ligament, is described below with the anterior talo-calcaneal joint.

The **synovial sac** is distinct from any other.

The **nerve-supply** is from the posterior tibial or one of its plantar branches.

The **arteries** are, a branch from the posterior tibial, which enters at the medial end of the sinus pedis; and twigs from the tarsal, lateral malleolar, and the peroneal, which enter at the lateral end of the sinus.

(ii) *The Anterior Talo-calcaneal Joint*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

This joint is formed by the anterior facet on the upper surface of the calcaneus and the facets on the lower surface of the neck and head of the talus; it is bounded on the sides and behind by ligaments, and communicates anteriorly with the talo-navicular joint. The ligaments are:—

Interosseous.	Medial talo-calcaneal.
	Lateral calcaneo-navicular.

The **interosseous ligament** by its anterior laminæ limits this joint posteriorly. It has been already described.

The **medial talo-calcaneal** ligament (second portion; see above) consists of short fibres attached above to the medial surface of the neck of the talus, and below to the upper edge of the free border of the sustentaculum tali, blending posteriorly with the medial extremityof the interosseous ligament, and anteriorly with the upper border of the plantar calcaneo-navicular ligament. It is strengthened by the deltoid ligament, the anterior fibres of which are also attached to the plantar calcaneo-navicular ligament.

The **lateral calcaneo-navicular** (figs. 334 and 335) limits this, as well as the talo-navicular joint, on the lateral side. It is a strong, well-marked band, extending from the rough upper surface of the calcaneus, lateral to the anterior facet, to a slight groove on the lateral surface of the navicular near the posterior margin. It blends below with the plantar calcaneo-navicular, and above with the talo-navicular ligament. Its fibres run obliquely forward and medially. The deltoid ligament and middle fasciculus of the lateral ligament of the ankle-joint also add to the security of these two joints, and assist in limiting movements between the bones by passing over the talus to the calcaneus.

The **synovial membrane** is the same as that of the talo-navicular joint. The **arteries** and **nerves** are derived from the same sources as those of the medio-tarsal joints.

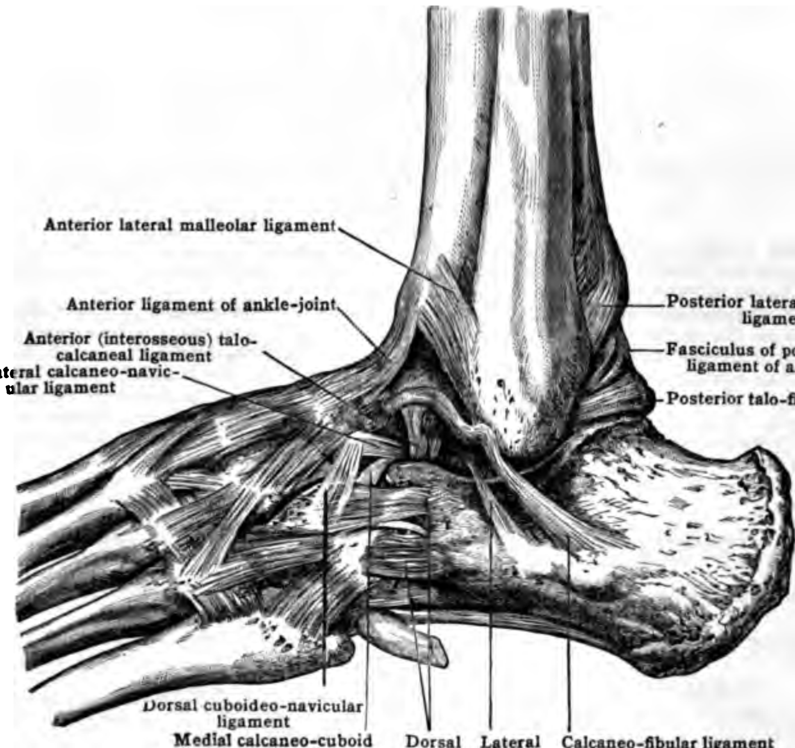
The **movements** of which these two joints are capable are adduction and abduction, with some amount of rotation. Adduction, or inclination of the sole medialward, is combined with some medial rotation of the toes, and some lateral rotation of the heel; while abduction, or inclination of the foot lateralward, is associated with turning of the toes laterally and the heel medially. Thus the variety and the range of movements of the foot on the leg, which at the ankle are almost limited to flexion and extension, are increased. The cuboid moves with the calcaneus, while the navicular revolves on the head of the talus.

In walking, the heel is first placed on the ground; the foot is slightly adducted; but as the body swings forward, first the lateral then the medial toes touch the ground, the talus presses against the navicular and sinks upon the plantar calcaneo-navicular ligament; the foot then becomes slightly abducted. When the foot is firmly placed on the ground, the weight is transmitted to it obliquely downward and medially, so that if the ligaments between the calcaneus and talus did not check abduction, medial displacement of the talus from the tibio-fibular arch would only be prevented by the tendons passing round the medial ankle (especially the *tibialis posterior*). If the ligaments be too weak to limit abduction, the weight of the body increases it, and forces the medial malleolus and talus downward and medially, giving rise to flat foot.

The advantages of the obliquity and peculiar arrangement of the posterior talo-calcaneal articulation are seen in walking:—(i) for the posterior facet of the calcaneus receives

the whole weight of the body when the heel is first placed on the ground; (ii) by the upward pressure of this facet against the talus it transfers the weight to the ball of the toes as the heel is raised, the posterior edge of the sustentaculum tali and the anterior and lateral part of the upper surface of the calcaneus preventing the talus from being displaced too far forward by the superincumbent weight; and (iii) the calcaneus serves to suspend the talus when, with the heel raised by muscular action, the other foot is being swung forward.

FIG. 334.—LATERAL VIEW OF THE LIGAMENTS OF THE FOOT AND ANKLE.



(b) THE ARTICULATIONS OF THE ANTERIOR PART OF THE TARSUS

These include (i) the cuboideo-navicular; (ii) cuneo-navicular; (iii) inter-cuneiform; and (iv) cuneo-cuboid joints.

(i) *The Cuboideo-navicular Union*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The joint cavity is only occasionally present and this joint is often included in the transverse tarsal.

The ligaments which unite the cuboid and navicular are:—

Dorsal. Plantar. Interosseous.

The **dorsal cuboideo-navicular ligament** (fig. 334) runs forward and laterally from the lateral end of the dorsal surface of the navicular to the middle third of the medial border of the cuboid on its dorsal aspect, passing over the posterior lateral angle of the third cuneiform bone. It is wider laterally.

The **plantar cuboideo-navicular ligament** is a well-marked strong band, which runs forward and laterally, from the plantar surface of the navicular to the depression on the medial surface of the cuboid, and slightly into the plantar surface just below it.

The **interosseous cuboideo-navicular ligament** is a strong band which passes between the apposed surfaces of these bones from the dorsal to the plantar ligaments. Some of its posterior fibres reach the plantar surface of the foot behind the cuboideo-navicular ligament, and radiate laterally and backward over the medial border of the cuboid to blend with the anterior extremity of the plantar calcaneo-cuboid ligament.

(ii) *The Cuneo-navicular Articulation*

Class.—*Diarthrosis*. **Subdivision.**—*Arthrodia*.

The ligaments uniting the navicular with the three cuneiform bones are:—

Dorsal. Medial. Plantar.

The **dorsal cuneo-navicular ligament** is very strong, and stretches as a continuous structure on the dorsal surface of the navicular, between the tubercle of the navicular on the medial side, and the dorsal cuboideo-navicular ligament laterally, passing forward and a little laterally to the dorsal surfaces of the three cuneiform bones.

The **medial cuneo-navicular ligament** is a very strong thick band which connects the tubercle of the navicular with the medial surface of the first cuneiform bone. It is continuous with the dorsal and plantar ligaments. Its lower border touches the tendon of the *tibialis posterior*.

The **plantar cuneo-navicular ligament** forms, like the dorsal, a continuous structure extending between the plantar surfaces of the bones. Its fibres pass forward and laterally. It is in relation below with the tendon of the *tibialis posterior*.

It must be noticed that the expanded tendon of insertion of the *tibialis posterior*, and the ligaments uniting the navicular with the cuboid and cuneiform bones, pass forward and laterally, while the *peroneus longus* tendon and the ligaments uniting the first and second rows of bones, except the medial half of the dorsal talo-navicular ligaments, pass forward and medially. This arrangement is admirably adapted to preserve the arches of the foot, and especially the transverse arch. Had these tendons and ligaments run directly forward, all the strain on the transverse arch would have fallen on the interosseous ligaments, but as it is, the arch is braced up by the above-mentioned structures.

(iii) *The Intercuneiform and* (iv) *The Cuneo-cuboid Articulations*

Class.—*Diarthrosis*. **Subdivision**—*Arthrodia*.

The uniting ligaments of these bones are divided into three sets:—

Dorsal. Interosseous. Plantar.

The **dorsal ligaments** are three in number, two, the **dorsal intercuneiform, connecting the** three cuneiform bones, and a third, the dorsal **cuneo-cuboid**, uniting the third cuneiform with the cuboid. They pass between the contiguous margins of the bones, and are blended behind with the dorsal ligaments of the cuboideo-navicular and cuneo-navicular joints.

The **plantar ligaments** are two in number: a very strong one, the **plantar intercuneiform**, passes laterally and forward from the lateral side of the base of the first cuneiform to the apex of the second cuneiform, winding somewhat to its lateral side. The second, the **plantar cuneo-cuboid**, connects the apex of the third cuneiform with the anterior half of the medial surface of the cuboid along its plantar border, joining with the plantar cuboideo-navicular ligament behind.

The **interosseous ligaments** are three in number. They are strong and deep masses of ligamentous tissue which connect the second cuneiform with the first and third cuneiform bones, and the third cuneiform with the cuboid; occupying all the non-articular portions of the apposed surfaces of the bones. The ligaments extend the whole vertical depth between the second cuneiform and the third, and the third cuneiform and the cuboid, and blend with the dorsal and plantar ligaments; they are situated in front of the articular facets, and completely shut off the synovial cavity behind from that in front. The ligament between the first and second cuneiform bones occupies the inferior and anterior two-thirds of the apposed surfaces, and does not generally extend high enough to separate the synovial cavity of the anterior tarsal joint from that of the second and third metatarsal and cuneiform bones. If it does extend to the dorsal surface, it divides the facets completely from one another, making a seventh synovial sac in the foot.

The **synovial cavity** will be described later on.

The **arterial supply** is from the metatarsal and plantar arteries.

The **nerves** are derived from the deep peroneal and medial and lateral plantar.

The **movement** permitted in these joints is very limited, and exists only for the purpose of adding to the general pliancy and elasticity of the tarsus without allowing any sensible alteration in the position of the different parts of the foot, as the medio-tarsal and talo-calcaneal joints do. It is simply a gliding motion, and either deepens or widens the transverse arch. The third cuneiform being wedged in between the others is less movable, and so forms a pivot upon which the rest can move. The movement is more produced by the weight of the body than by direct muscular action; and of the muscles attached to this part of the tarsus, all deepen the arch save the tibialis anterior, which pulls the first cuneiform up, and so tends to widen it.

(c) The Transverse Tarsal Joints

The articulations of the anterior and posterior portions of the tarsus, although in the same transverse line, consist of two separate joints, viz., (i) a medial, the talo-navicular, which communicates with the anterior talo-calcaneal articulation; and (ii) a lateral, the calcaneo-cuboid, which is complete in itself. The movements of the anterior upon the posterior portions of the foot take place at these joints simultaneously. It will be most convenient to deal with the joints separately as regards the ligaments; while the arteries, nerves, and movements will be considered together.

(i) *The Talo-navicular Articulation*

Class.—*Diarthrosis.* **Subdivision.**—*Enarthrodia.*

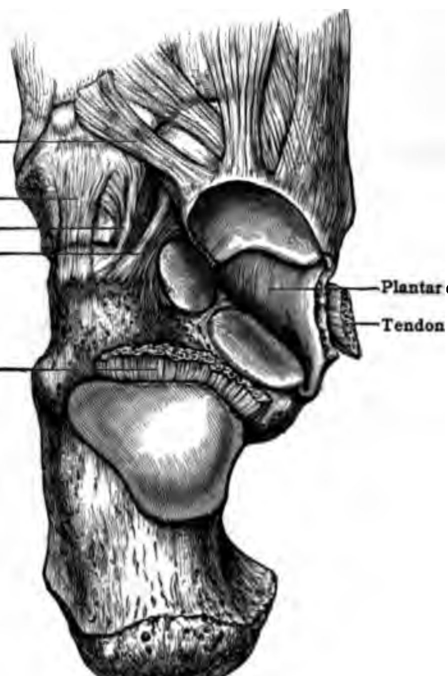
This is the only ball-and-socket joint in the tarsus. It communicates with the anterior talo-calcaneal articulation, and two of the ligaments which close it in do not touch the talus, but pass from the calcaneus to the navicular. The uniting ligaments include, in addition to the articular capsule, the following:—

Lateral calcaneo-navicular. Plantar calcaneo-navicular
Talo-navicular.

The **lateral calcaneo-navicular** has been already described (p. 302).

The **plantar calcaneo-navicular** ligament (figs. 335 and 336) is an exceedingly dense, thick plate of fibro-elastic tissue. It extends from the sustentaculum tali and the under surface of the calcaneus in front of a ridge curving laterally to the anterior tubercle of that bone, to the

Fig. 335.—View of the Foot from above, with the Talus removed to show the Plantar and Lateral Calcaneo-navicular Ligaments



whole width of the inferior surface of the navicular, and also to the medial surface of the navicular behind the tubercle. Medially it is blended with the anterior portion of the deltoid ligament of the ankle, and laterally with the lower border of the lateral calcaneo-navicular ligament. It is thickest along the medial border. Its upper surface loses the well-marked fibrous appearance which the ligament has in the sole, and becomes smooth and faceted. In contact with the under surface of the ligament the tendon of the *tibialis posterior* passes, giving considerable support to the head of the talus by assisting the power and protecting the spring of the ligament. The fibres of the ligament run forward and medially. On account of its elasticity it is sometimes termed the **spring ligament**.

The **talo-navicular ligament** is a broad, thin, but well-marked layer of fibres which passes from the dorsal and lateral surfaces of the neck of the talus to the whole length of the dorsal surface of the navicular. Many of the fibres converge to their insertion on the navicular. The fibres low down on the lateral side blend a little way from their origin with the upper edge of the lateral calcaneo-navicular ligament, and then pass forward and medially to the navicular; those next above pass obliquely and with a distinct twist over the upper and lateral side of the head of the talus to the centre of the dorsum of the navicular, overlapping fibres from the medial side of the talus as well as some from the anterior ligament of the ankle-joint.

Synovial membrane.—The talo-navicular is lined by the same synovial membrane as the anterior talo-calcaneal joint.

(ii) *The Calcaneo-cuboid Articulation*

Class.—*Diarthrosis.* **Subdivision.**—*Saddle-shaped Arthrodia.*

The ligaments which are supplementary to the articular capsule and unite the bones forming the outer part of the medio-tarsal joint are:—

Medial calcaneo-cuboid.	Dorsal calcaneo-cuboid.
Long plantar.	Plantar calcaneo-cuboid.

The **medial calcaneo-cuboid ligament** (fig. 335) is a strong band of fibres attached to the calcaneus along the medial part of the non-articular ridge above the articular facet for the cuboid, and also to the upper part of the medial surface close to the articular margin, and passes forward to be attached to the depression on the medial surface of the cuboid, and also to the rough angle

Fig. 336.—Ligaments of the Sole of the Left Foot.

between the medial and inferior surfaces. At the calcaneus this ligament is closely connected with the lateral calcaneo-navicular ligament. Toward the sole it is connected with the plantar calcaneo-cuboid ligament, and superiorly with the dorsal calcaneo-cuboid.

The **dorsal calcaneo-cuboid** (fig. 335) is attached to the dorsal surfaces of the two bones, extending low down laterally to blend with the lateral part of the plantar calcaneo-cuboid ligament. Over the medial half, or more, the ligament stretches some distance beyond the margins of the articular surfaces, reaching well forward upon the cuboid to be attached about midway between its anterior and posterior borders; but toward the lateral side, the ligament is much shorter, and is attached to the cuboid behind its tubercle.

The **long plantar ligament** (fig. 336) is a strong, dense band of fibres which is attached posteriorly to the whole of the inferior surface of the calcaneus between the posterior tubercles and the rounded eminence (the anterior tubercle) at the anterior end of the bone. Most of its fibres pass directly forward, and are fixed to the lateral two-thirds or more of the oblique ridge behind the peroneal groove on the cuboid, while some pass further forward and medially, expanding into a broad layer, and are inserted into the bases of the second, third, fourth, and medial half of the fifth metatarsal bones. This anterior expanded portion completes the canal for the *peroneus longus tendon*, and from its under surface arise the *oblique adductor hallucis* and the *flexor quinti digiti brevis* muscles.

The **plantar calcaneo-cuboid** (short plantar) (fig. 336) is attached to the rounded eminence (anterior tubercle) at the anterior end of the under surface of the calcaneus, and to the bone in front of it, and then takes an oblique course forward and medially, and is attached to the whole of the depressed inferior surface of the cuboid behind the oblique ridge, except its lateral angle. It is strongest near its lateral edge, and is formed by dense strong fibres.

The **synovial membrane** is distinct from that of any other tarsal joint.

The **arterial supply** of the medio-tarsal joints is from the anterior tibial, from the tarsal and metatarsal branches of the dorsalis pedis, and from the plantar arteries.

The **nerve-supply** of the medio-tarsal joints is from the lateral division of the deep peroneal, and occasionally from the superficial peroneal or lateral plantar.

Relations.—On the *dorsal aspect* of the mid-tarsal joint lie the tendons of the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius, the muscular part of the extensor digitorum brevis, the dorsalis pedis artery, and the anterior tibial nerve. On its *plantar aspect* are the tendons of the flexor digitorum longus and hallucis longus, quadratus plantæ (accessorius), and the medial and lateral plantar vessels and nerves. It is crossed laterally by the tendons of the peroneus longus and brevis and medially by the tendon of the tibialis posterior.

The **movements** which take place at the medio-tarsal joints are mainly flexion and extension, with superadded side-to-side and rotatory movements. Flexion at these joints is simultaneous with extension of the ankle, and *vice versa*. Flexion and extension do not take place upon a transverse, but round an oblique, axis which passes from the medial to the lateral side, and somewhat backward and downward through the talus and calcaneus.

Combined with flexion and extension is also some rotatory motion round an antero-posterior axis which turns the medial or lateral border of the foot upward. There is also a fair amount of side-to-side motion whereby the foot can be inclined medially (i. e., adducted) or laterally (i. e., abducted).

These movements of the medio-tarsal joint occur in conjunction with those of the ankle and talo-calcaneal joints. Rotation at the talo-calcaneal joint is, however, round a vertical axis in a horizontal plane, and so turns the toes medially or laterally; whereas at the medio-tarsal union the axis is antero-posterior and the medial or lateral edge of the foot is turned upward. Gliding at the talo-calcaneal joint elevates or depresses the edge of the foot, while at the medio-tarsal it adducts or abducts the toes without altering the relative position of the calcaneus to the talus.

Thus flexion at the medio-tarsal joint is associated with adduction and medial rotation of the foot, occurring simultaneously with extension of the ankle; and extension at the medio-tarsal joint is associated with abduction and lateral rotation, occurring simultaneously with flexion of the ankle.

Flexion and medial rotation are far more free than extension and lateral rotation, which latter movements are arrested by the ligaments of the sole as soon as the foot is brought into the position in which it rests on the ground.

Although the talo-navicular is a ball-and-socket joint, yet, owing to the union of the navicular with the cuboid, its movements are limited by the shape of the calcaneo-cuboid joint; this latter being concavo-convex from above downward, prevents rotation round a vertical axis, and also any side-to-side motion except in a direction obliquely downward and medially, and upward and laterally. This is also the direction of freest movement at the talo-navicular joint. Movement is also limited by the ligamentous union of the calcaneus with the navicular. The twisting movement of the foot, such as turning it upon its medial or lateral edge, and the increase or diminution of the arch, take place at the tarsal joints, especially the medio-tarsal and talo-calcaneal articulations. Here too those changes occur which, owing to paralysis of some muscles or contraction of others, result in talipes equino-varus, or valgus.

Muscles which act on the mid-tarsal joint.—*Medial rotators.*—Tibialis anterior and posterior acting simultaneously; they are aided by the flexor digitorum longus and flexor hallucis longus. *Lateral rotators.*—The peronei longus, brevis, and tertius, acting simultaneously. They are aided by the extensor digitorum longus.

6. THE TARSO-METATARSAL ARTICULATIONS

There may be said to be three articulations between the tarsus and metatarsus, viz.:—

(*a*) The medial, between the first cuneiform and first metatarsal bones.

(*b*) The intermediate, between the three cuneiform and second and third metatarsal bones.

(*c*) The lateral, or cubo-metatarsal, between the cuboid and fourth and fifth metatarsal bones.

The **talo-navicular ligament** is a broad, thin, but well-marked layer of fibres which passes from the dorsal and lateral surfaces of the neck of the talus to the whole length of the dorsal surface of the navicular. Many of the fibres converge to their insertion on the navicular. The fibres low down on the lateral side blend a little way from their origin with the upper edge of the lateral calcaneo-navicular ligament, and then pass forward and medially to the navicular; those next above pass obliquely and with a distinct twist over the upper and lateral side of the head of the talus to the centre of the dorsum of the navicular, overlapping fibres from the medial side of the talus as well as some from the anterior ligament of the ankle-joint.

Synovial membrane.—The talo-navicular is lined by the same synovial membrane as the anterior talo-calcaneal joint.

(ii) *The Calcaneo-cuboid Articulation*

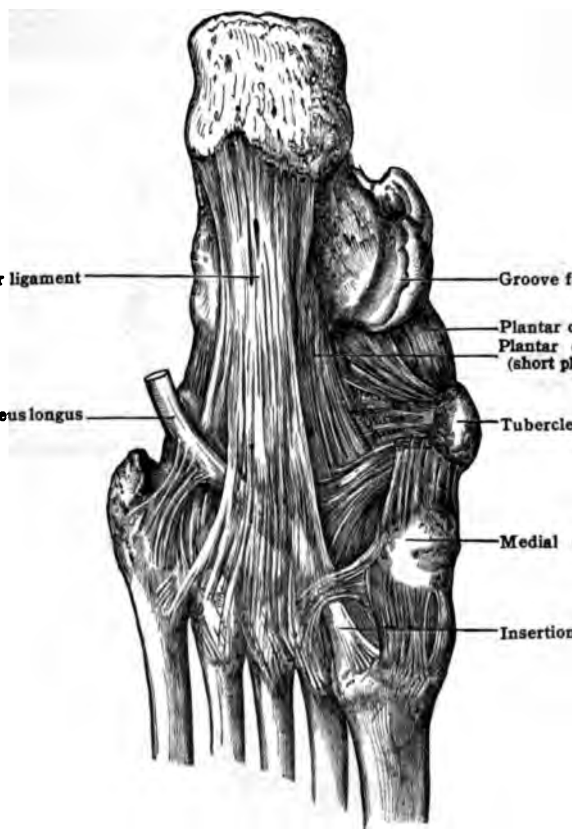
Class.—*Diarthrosis.* **Subdivision.**—*Saddle-shaped Arthrodia.*

The ligaments which are supplementary to the articular capsule and unite the bones forming the outer part of the medio-tarsal joint are:—

Medial calcaneo-cuboid.	Dorsal calcaneo-cuboid.
Long plantar.	Plantar calcaneo-cuboid.

The **medial calcaneo-cuboid ligament** (fig. 335) is a strong band of fibres attached to the calcaneus along the medial part of the non-articular ridge above the articular facet for the cuboid, and also to the upper part of the medial surface close to the articular margin, and passes forward to be attached to the depression on the medial surface of the cuboid, and also to the rough angle

FIG. 336.—LIGAMENTS OF THE SOLE OF THE LEFT FOOT.



between the medial and inferior surfaces. At the calcaneus this ligament is closely connected with the lateral calcaneo-navicular ligament. Toward the sole it is connected with the plantar calcaneo-cuboid ligament, and superiorly with the dorsal calcaneo-cuboid.

The **dorsal calcaneo-cuboid** (fig. 335) is attached to the dorsal surfaces of the two bones, extending low down laterally to blend with the lateral part of the plantar calcaneo-cuboid ligament. Over the medial half, or more, the ligament stretches some distance beyond the margins of the articular surfaces, reaching well forward upon the cuboid to be attached about midway between its anterior and posterior borders; but toward the lateral side, the ligament is much shorter, and is attached to the cuboid behind its tubercle.

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The **plantar calcaneo-cuboid** (short plantar) (fig. 336) is attached to the rounded eminence (anterior tubercle) at the anterior end of the under surface of the calcaneus, and to the bone in front of it, and then takes an oblique course forward and medially, and is attached to the whole of the depressed inferior surface of the cuboid behind the oblique ridge, except its lateral angle. It is strongest near its lateral edge, and is formed by dense strong fibres.

The **synovial membrane** is distinct from that of any other tarsal joint.

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The **nerve-supply** of the medio-tarsal joints is from the lateral division of the deep peroneal, and occasionally from the superficial peroneal or lateral plantar.

Relations.—On the *dorsal aspect* of the mid-tarsal joint lie the tendons of the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius, the muscular part of the extensor digitorum brevis, the dorsalis pedis artery, and the anterior tibial nerve. On its *plantar aspect* are the tendons of the flexor digitorum longus and hallucis longus, quadratus plantæ (accessorius), and the medial and lateral plantar vessels and nerves. It is crossed laterally by the tendons of the peroneus longus and brevis and medially by the tendon of the tibialis posterior.

The **movements** which take place at the medio-tarsal joints are mainly flexion and extension, with superadded side-to-side and rotatory movements. Flexion at these joints is simultaneous with extension of the ankle, and *vice versa*. Flexion and extension do not take place upon a transverse, but round an oblique, axis which passes from the medial to the lateral side, and somewhat backward and downward through the talus and calcaneus.

Combined with flexion and extension is also some rotatory motion round an antero-posterior axis which turns the medial or lateral border of the foot upward. There is also a fair amount of side-to-side motion whereby the foot can be inclined medially (i. e., adducted) or laterally (i. e., abducted).

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Muscles which act on the mid-tarsal joint.—*Medial rotators.*—Tibialis anterior and posterior acting simultaneously; they are aided by the flexor digitorum longus and flexor hallucis longus. *Lateral rotators.*—The peronei longus, brevis, and tertius, acting simultaneously. They are aided by the extensor digitorum longus.

6. THE TARSO-METATARSAL ARTICULATIONS

There may be said to be three articulations between the tarsus and metatarsus, viz.:—

(*a*) The medial, between the first cuneiform and first metatarsal bones.

(*b*) The intermediate, between the three cuneiform and second and third metatarsal bones.

(*c*) The lateral, or cubo-metatarsal, between the cuboid and fourth and fifth metatarsal bones.

(a) The Medial Tarso-metatarsal Joint

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

A complete **articular capsule** unites the first metatarsal with the first cuneiform, the fibres of which are very thick on the inferior and medial aspects; those on the lateral side pass from behind forward in the interval between the interosseous ligaments which connect the two bones forming this joint with the second metatarsal. The ligament on the plantar aspect is by far the strongest, and blends at the cuneiform bone with the cuneo-navicular ligament.

(b) The Intermediate Tarso-metatarsal Joint

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

Into this union there enter the three cuneiform and second and third metatarsal bones, which are bound together by the following ligaments (supplementary to the articular capsule): dorsal, plantar, interosseous.

The dorsal ligaments.—1. Some short fibres cross obliquely from the lateral edge of the first cuneiform bone to the medial border of the base of the second metatarsal bone; they take the place of a dorsal metatarsal ligament, which is wanting between the first and second metatarsal bones.

2. Between the second cuneiform and the base of the second metatarsal bone some fibres run directly forward.

3. The third cuneiform is connected with (1) the lateral corner of the second metatarsal bone by a narrow band passing obliquely medially; (2) with the third metatarsal by fibres passing directly forward; and (3) with the fourth metatarsal by a short band passing obliquely laterally to the medial edge of its base.

The plantar ligaments.—A strong ligament unites the first cuneiform and the bases of the second and third metatarsal bones. The *tibialis posterior* is inserted into these bones close beside it. Other slender ligaments connect the second cuneiform with the second, and the third cuneiform with the third metatarsal bones.

The interosseous ligaments.—(1) A strong broad interosseous ligament extends between the lateral surface of the first cuneiform and the medial surface of the base of the second metatarsal bone. It is attached to both bones below and in front of the articular facets, and separates the intermediate from the medial tarso-metatarsal joint. (2) A second band is attached behind to a fossa on the anterior and lateral edge of the third cuneiform and to the interosseous ligament between it and the cuboid, and passes horizontally forward to be attached to the whole depth of the fourth metatarsal bone behind its medial facet, and to the opposed surfaces of the third and fourth below the articular facets upon their sides. It separates the middle tarsometatarsal, and intermetatarsal between the third and fourth bones, from the cubo-metatarsal joint. It is more firmly connected with the third bone than with the fourth. (3) A slender ligament composed only of a few fibres often passes from a small tubercle on the medial and anterior edge of the third cuneiform to a groove on the lateral edge of the second metatarsal bone between the two facets upon their sides.

The **synovial membrane** is prolonged forward from that of the naviculari-cuneiform and inter-cuneiform articulations.

The **arteries for the tarso-metatarsal joints** are derived:—(1) for the medial, from the dorsalis pedis and medial plantar; (2) for the rest, twigs from the arcuate and deep plantar arch.

The **nerve-supply** comes from the deep peroneal and plantar nerves.

The **movements** permitted at these joints are flexion and extension of the metatarsus on the tarsus; and at the medial and lateral divisions, slight adduction and abduction. In the lateral, the side-to-side motion is freer than in the medial joint, and freest between the fifth metatarsal bone and the cuboid. In the medial joint, flexion is combined with slight abduction and extension with abduction.

There is also a little gliding, which allows the transverse arch to be increased or diminished in depth; the medial and lateral two bones sliding downward, and the two middle a little upward, when the arch is increased; and *vice versa* when the arch is flattened.

(c) The Lateral or Cubo-metatarsal Joint

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The bones comprising this joint are the fourth and fifth metatarsal and the anterior surface of the cuboid, firmly connected on all sides by the articular capsule, strengthened by the following ligaments:—

Dorsal. Plantar. Interosseous.

The **plantar cubo-metatarsal ligament** is a broad, well-marked ligament, which extends from the cuboid behind to the bases of the fourth and fifth metatarsal bones in front. It is

continuous along the groove at the base of the fifth metatarsal bone with the dorsal ligament, and as it passes round the lateral border of the foot it is somewhat thickened, and may be described as the **lateral cubo-metatarsal ligament**. On its medial side it joins the interosseous ligaments, thus completing the capsule below. It is not a thick structure, and to see it the long plantar ligament, the peroneus longus, and lateral slip of the tibialis posterior must be removed; the attachment of these structures to the fourth and fifth metatarsal bones considerably assists to unite them with the tarsus.

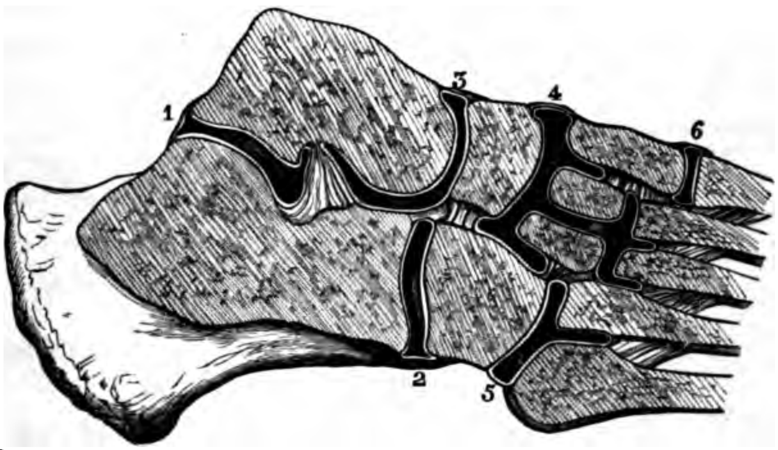
The **dorsal cubo-metatarsal ligament** is composed of fibres which pass obliquely outward and forward from the cuboid to the bases of the fourth and fifth metatarsal bones. They complete the capsule above, and are continuous laterally with the lateral cubo-metatarsal ligament.

The **interosseous ligament** shuts off the cubo-metatarsal from the middle tarso-metatarsal joint. It is attached to the third cuneiform behind, and to the whole depth of the fourth metatarsal behind its medial facet, and to the apposed surfaces of the third and fourth bones below their articular facets. It is continuous below with the plantar ligament.

The **synovial membrane** is separate from the other synovial sacs of the tarsus, and is continued between the fourth and fifth metatarsal bones.

Relations.—The line of the tarso-metatarsal joints is crossed dorsally by the tendons of the long and short extensor muscles of the toes and the tendon of the peroneus tertius. On the plantar aspect it is in relation with the oblique adductor of the great toe, the short flexor of the great toe, the lateral plantar artery, and the tendon of the peroneus longus. Its medial end is subcutaneous except that it is crossed, near the plantar surface, by a slip of the tendon of the tibialis anterior, and its lateral end is crossed by the tendon of the peroneus brevis.

FIG. 337.—SECTION TO SHOW THE SYNOVIAL CAVITIES OF THE FOOT.



1. Posterior talo-calcaneal. 2. Calcaneo-cuboid. 3. Anterior talo-calcaneo-navicular.
4. Tarsal. 5. Cubo-metatarsal. 6. First metatarso-cuneiform.

7. THE INTERMETATARSAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The bases of the metatarsal bones are firmly held in position by dorsal, plantar, and interosseous ligaments, supplementing the articular capsules. The first occasionally articulates by means of a distinct facet with the second metatarsal (figs. 245 and 246).

The **dorsal ligaments** are broad, membranous bands passing between the four lateral toes on their dorsal aspect; but in place of one between the first and second metatarsal bones, a ligament extends from the first cuneiform to the base of the second metatarsal bone.

The **plantar ligaments** are strong, thick, well-marked ligaments which connect the bones on their plantar aspect.

The **interosseous ligaments** are three in number, very strong, and are situated at the points of union of the shaft with the bases of the bones, and fill up the sulci on their sides. They limit the synovial cavities in front of the synovial facets.

The common **synovial membrane** of the tarsus extends between the second and third, and third and fourth bones; that of the cubo-metatarsal joint extending between the fourth and fifth.

The **arterial** and **nerve-supply** is the same as for the tarso-metatarsal joints.

The **movements** consist merely of gliding, so as to allow the raising or widening of the transverse arch. Considerable flexibility and elasticity are thus given to the anterior part of the foot, enabling it to become moulded to the irregularities of the ground.

THE UNION OF THE HEADS OF THE METATARSAL BONES

The **heads of the metatarsal bones** are connected on their plantar aspect by the **transverse ligament** [Ligg. capitulorum transversa], consisting of four bands

of fibres passing transversely from bone to bone, blending with the fibro-cartilaginous or sesamoid plates of the metatarso-phalangeal joints, and the sheaths of the flexor tendons where they are connected with the fibro-cartilages. It differs from the corresponding ligament in the hand by having a band from the first to the second metatarsal bone.

8. THE METATARSO-PHALANGEAL ARTICULATIONS

(a) THE METATARSO-PHALANGEAL JOINTS OF THE FOUR LATERAL TOES

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

These joints are formed by the concave proximal ends of the first phalanges articulating with the rounded heads of the metatarsal bones, and united by articular capsules strengthened by the following ligaments:—

Collateral. Dorsal. Plantar accessory.

The two **collateral ligaments** are strong bands passing from a ridge on each side of the head of the metatarsal bone to the sides of the proximal end of the first phalanx, and also to the sides of the sesamoid plate which unites the two bones on their plantar surfaces. On the dorsal aspect they are united by the dorsal ligament.

The **dorsal ligament** consists of loose fine fibres of areolo-fibrous tissue, extending between the collateral ligaments, thus completing a capsule. It is connected by fine fibres to the under surface of the extensor tendons, which pass over and considerably strengthen this portion of the capsule.

The **plantar accessory ligament** or sesamoid plate helps to deepen the shallow facet of the phalanx for the head of the metatarsal bone, and corresponds to the accessory volar ligament of the fingers. It is firmly connected to the collateral ligaments and the transverse ligament, and is grooved inferiorly where the flexor tendons pass over it. It serves to prevent dorsal dislocation of the phalanx.

The second metatarso-phalangeal joint is 6 mm. (¼ in.) in front of both the first and third metatarso-phalangeal joints.

The third metatarso-phalangeal joint is 6 mm. (¼ in.) in front of the fourth, and the fourth 9 mm. (⅜ in.) in front of the fifth.

The head of the fifth metatarsal is in line with the neck of the fourth.

Thus the lateral side of the longitudinal arch of the foot is shorter than the medial, it is also distinctly shallower.

(b) THE METATARSO-PHALANGEAL JOINT OF THE GREAT TOE

The metatarso-phalangeal joint of the great toe differs from the rest in the following particulars:—

(1) The bones are on a larger scale, and the articular surfaces are more extensive.

(2) There are two grooves on the plantar surface of the metatarsal bone, one on each side of the median line, for the sesamoid bones.

(3) The sesamoid bones replace the accessory plantar ligament (sesamoid plate). They are two small hemispherical bones developed in the tendons of the flexor hallucis brevis, convex below, but flat above where they play in grooves on the head of the metatarsal bone; they are united by a strong transverse ligamentous band, which is smooth below and forms part of the channel along which the long flexor tendon plays. They are firmly united to the base of the phalanx by strong short fibres, but to the metatarsal bone they are joined by somewhat looser fibres. At the sides they are connected with the collateral ligaments and the sheath of the flexor tendon. They provide shifting leverage for the *flexor hallucis brevis* as well as for the *flexor hallucis longus*.

The **arteries** come from the digital and metatarsal branches; and the **nerves** from the cutaneous digital, or from small twigs of the nerves to the interossei muscles.

The **movements** permitted are: flexion, extension, abduction, adduction, and circumduction. Flexion is more free than extension, and is limited by the extensor tendons and dorsal ligaments; extension is limited by the flexor tendons, the plantar fibres of the collateral ligaments, and the sesamoid plates. The side-to-side motion is possible from the shape of the bony surfaces, but is very limited, being most marked in the great toe. It is limited by the collateral ligaments and sesamoid plates.

9. THE INTERPHALANGEAL JOINTS

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The articulations between the first and second and second and third phalanges *of the toes are* similar to those of the fingers, with this important difference, that

the bones are smaller and the joints, especially between the second and third phalanges, are often ankylosed. The ligaments which unite them include, in addition to the articular capsule:—

Collateral.	Dorsal.	Accessory plantar.

The two **collateral ligaments** are well marked, and pass on each side of the joints from a little rough depression on the head of the proximal, to a rough border on the side of the base of the distal phalanx of the joint.

The **dorsal ligament** is thin and membranous, and extends across the joint from one collateral ligament to the other beneath the extensor tendon, with the deep surface of which it is connected and by which it is strengthened.

The **accessory plantar ligament** covers in the joint on the plantar surface. It is a fibrocartilaginous plate, connected at the sides with the collateral ligaments, and with the bones by short ligamentous fibres; the plantar surface is smooth, and grooved for the flexor tendons.

The **arteries and nerves** are derived from the corresponding digital branches.

The only **movements** permitted at these joints are flexion and extension.

At the interphalangeal joint of the great toe there is very frequently a small sesamoid bone which plays on the plantar surface of the first phalanx, in the same way as the sesamoid bones of the metatarso-phalangeal joint play upon the plantar surface of the head of the metatarsal bone.

Relations of the muscles acting on the metatarso-phalangeal and interphalangeal joints of the foot.—If the student will refer to the accounts given of the relations of the corresponding joints in the hand and of the actions of the muscles upon those joints, and if he contrasts and compares the muscles of the hand with those of the foot, he will readily be able to construct tables of the relations of the metatarso-phalangeal and interphalangeal joints of the foot, and tables of the muscles acting upon the joints.

References.—A complete bibliography for the joints is given in the "Handbuch der Anatomie und Mechanik der Gelenke," by Professor Rudolf Fick (in von Bardeleben's Handbuch der Anatomie). References are also given in the larger works on human anatomy by Quain, Rauber-Kopsch, Poirier-Charpy, etc. References to the most recent literature may be found in Schwalbe's Jahresbericht, the Index Medicus and the various anatomical journals.

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